The 2010 Foot-and-Mouth Disease Epidemic in Japan

Norihiko MUROGA1), Yoko HAYAMA1), Takehisa YAMAMOTO2), Akihiro KUROGI3), Tomoyuki TSUDA4) and Toshiyuki TSUTSUI1)*

1)Epidemiological Research Team, National Institute of Animal Health, 3–1–5 Kannondai, Tsukuba, Ibaraki 305–0856, Japan
2)Animal Health Division, Food Safety and Consumer Affairs Bureau Ministry of Agriculture, Forestry and Fisheries, 1–2–1 Kasumigaseki, Chiyoda-ku, Tokyo 100–8950, Japan
3)Nobeoka Livestock Hygiene Service Center, 4–2655–1 Onuki-machi, Nobeoka, Miyazaki 882–0803, Japan
4)Department of Planning and General Administration, National Institute of Animal Health, 3–1–5 Kannondai, Tsukuba, Ibaraki 305–0856, Japan

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ABSTRACT. Foot-and-mouth disease (FMD) occurred recently for the first time in a decade in Japan. The index case was detected on a beef-breeding farm in Miyazaki Prefecture, Southern Japan, on April 20, 2010. After confirmation of this first case, control measures such as stamping out, movement restriction and disinfection were implemented. However, these strategies proved insufficient to prevent the spread of FMD and emergency vaccination was adopted. Up until the last outbreak on July 4, 2010, a total of 292 outbreaks had been confirmed, with about 290,000 animals having been culled. The epidemic occurred in an area with a high density of cattle and pigs, making disease control difficult. Invasion of the disease into a high-density area aided its rapid spread and led to difficulties in locating suitable burial sites. Epidemiological investigations indicated that the disease was introduced into Japan approximately one month before detection. This delay in initial detection is considered to have allowed an increased number of outbreaks in the early stage of the epidemic. Nevertheless, the epidemic was contained within a localized area in Miyazaki Prefecture and was eradicated within three months because of intensive control efforts including emergency vaccination. Although this epidemic devastated the livestock industry in Japan, many lessons can be learnt for the future prevention and control of infectious diseases in animals.


In April 2010, an outbreak of foot-and-mouth disease (FMD), a highly infectious disease affecting cloven-hoofed animals, was reported in Miyazaki Prefecture in Southern Japan; the outbreak occurred for the first time in the country since 2000. Since early 2010, FMD caused by the O-type virus has spread across other East Asian countries; outbreaks occurred in Hong Kong in February and in Korea and Mongolia in April. China has also reported occurrences of O-type FMD since February 2010. Following the outbreak in Japan, Russia reported FMD cases near its borders with China and Mongolia in July. The sequence data obtained for the VP1 gene indicated that the O-type virus isolated in Japan belongs to topotype Southeast Asia, genotype Mya-98. This virus exhibited high homology to serotype O viruses isolated in Hong Kong, Korea and Russia in 2010, with percentage nucleotide identities of 99.22, 98.9 and 98.59%, respectively [5, 6]. This high degree of homology indicated that the FMD virus circulating widely in the East Asia region was the same as that causing the epidemic in Japan.

The 2000 FMD outbreak in Japan was also caused by the serotype O virus, and the index case was detected on a beef cattle farm in Miyazaki Prefecture, as in 2010. In 2000, the infected premises were limited to only four cattle farms, and a total of 740 cattle were culled during the epidemic. In the 2010 epidemic, approximately 290,000 animals were culled in order to eradicate the disease from Japan. Consequently, the 2010 epidemic caused serious losses to the livestock industry in the affected region.

In this paper, we describe the course of the epidemic and the countermeasures taken to control it in 2010. We then discuss the possible cause of the epidemic and lessons learnt from this experience that would aid in better disease control strategies for future outbreaks.

COURSE OF THE EPIDEMIC

The index case was confirmed at a beef-breeding farm in Miyazaki Prefecture. A private veterinarian first detected an abnormal symptom on this farm and reported it to the local veterinary service center on April 9. Since other infectious diseases had been ruled out by detailed examinations in the local veterinary service center, samples were sent to the National Institute of Animal Health (NIAH) for FMD testing on April 19. The NIAH confirmed FMD by reverse transcription-polymerase chain reaction (RT-PCR) tests on April 20. The FMD virus was later isolated from samples obtained at the index farm and confirmed to be serotype O.
After confirmation of the first case, infected cattle farms were continuously detected within a relatively limited area. However, on April 28, an outbreak was confirmed outside the movement restriction zone in Ebino, over 70 km from the previous outbreak area. A truck carrying animals before imposing movement restrictions was suspected as having been associated with this long-distance transmission. Four infected farms were detected in Ebino up to May 12, and all animals on these farms were culled within two days of disease detection. This rapid and decisive action resulted in rapid eradication of the disease from that area.

An outbreak of FMD was reported on April 28 on a pig farm located 6 km southeast of the index farm. After this report, the number of FMD cases on both pig and cattle farms rapidly increased (Fig. 1). By mid-May, the number of reported outbreaks had peaked to ten farms per day. The rapid increase in the number of infections caused a delay in livestock destruction on infected farms; animals on over 100 infected farms remained to be culled at the peak of the epidemic (Fig. 2). This delay made control of the spread of the disease difficult despite the implementation of strict movement restrictions. The government decided at that point to carry out emergency vaccination for all cattle.

![Fig. 1. Number of cases, by date reported, during the 2010 FMD epidemic in Japan.](image)

![Fig. 2. Livestock destruction at infected farms by date.](image)
and pig farms in the main infected area to restrict further spread of the disease.

Two weeks after initiating vaccination, the number of outbreaks had decreased (Fig. 1). Although infection was still confirmed outside the vaccination area after completing the vaccination program, further spread was immediately prevented to surrounding farms by rapid livestock destruction on infected farms within three days of detection. No further outbreaks were detected after July 4. After confirming the absence of FMD in the affected areas, all movement restrictions were phased out by July 27.

AFFECTED AREA

Miyazaki Prefecture is known to be the primary livestock-producing area of the country. It has 315,000 cattle and 915,000 pigs, accounting for 7 and 21%, respectively, of the Japanese livestock. The density of livestock farms is also high in Miyazaki Prefecture (highest density of cattle, 165.0 farms/100 km$^2$, and second highest density of pigs, 9.8 farms/100 km$^2$, in Japan). These figures indicate that FMD hit the areas where the risk of disease spread was highest because of the large number of both cattle and pig farms.

Geographically, most outbreaks (279/292) occurred within a limited area, approximately 20 km from south to north in the central area of Miyazaki Prefecture, although sporadic sites of infection were detected at distant locations (Fig. 3). The area most affected had a high density of cattle and pig farms relative to surrounding area due to it being a narrow plain located between mountains to the west and the sea to the east (Fig. 4).

CLINICAL SIGNS

In this epidemic, infected animals exhibited apparent clinical signs of FMD. Infected cattle continuously dribbled foamy saliva and pyrexia developed. Vesicles and erosions erupting on the tongue, hard palate and dental pad were typical in cattle, and cicatrization of these lesions was observed in several cases. Lesions in the bovine nasal cavity were mostly found as erosions rather than vesicles. During the visits of veterinary officials to farms immediately after notification, excessive salivation and lesions in the mouth or tongue were confirmed in cattle at over 80% of cattle farms, with infection later being confirmed by laboratory tests. Foot lesions in cattle were rare, being observed at only two infected cattle farms. On the other hand, foot erosions and hemorrhages, causing lameness, were common in infected pigs, being detected at over 90% of infected pig farms. In addition, snout lesions were also typical and observed at over 90% of infected pig farms. Infected sows on breeding farms often exhibited vesicles and erosions on the teats. Piglet mortality was observed on six breeding farms when veterinary officials visited farms soon after notification. Two infected goats, which were detected in a hobby flock during the epidemic, showed small erosions or crusts in their nasal cavities with positive results of serological tests.

MEASURES TAKEN TO MANAGE THE FMD EPIDEMIC

Stamping out and movement restrictions: The primary eradication strategy for FMD in Japan is stamping out and movement restriction. As soon as FMD was confirmed, control measures were implemented under the provisions of the relevant laws and guidelines. All infected and suspected animals on infected farms were culled. Contaminants, such as carcasses, feces, feed, bedding materials and compost, were buried or disinfected. These carcasses and contaminants were, in principle, buried in or near the infected farms; however, because the rapid increase in the number of infected farms made finding an adequate burial site for each infected farm difficult, common burial sites were used. Feces that could not be buried was subjected to viral inactivation through composting; it was stacked to allow heat to develop within it and left for at least 42 days on infected farms, ensuring that the temperature reached at least 60°C throughout the stack.

Movement restrictions were enforced within a radius of 10 km around an infected farm. Within this zone, the movement of all live cloven-hoofed animals, carcasses, feces, farm equipment and other commodities with the potential to transmit the FMD virus was prohibited. Outside the movement restriction zone, a shipment restriction zone
was established within a radius of 20 km from the infected farm. On the major roads around these movement restriction zones, a total of 403 disinfection posts were set at maximum in Miyazaki Prefecture to disinfect vehicles passing through these areas.

**Vaccination:** Preventive measures, such as movement restriction and stamping out, proved insufficient to prevent the spread of FMD in the worst-affected areas. Therefore, emergency vaccination was implemented using O-type vaccine (O1-Manisa) stockpiled for emergencies. Vaccination zones with a 10 km radius were established around infected farms found until May 18. All cloven-hoofed animals, except those under 14 days of age, were targeted. Vaccination was conducted from the perimeter of the zone inwards, giving priority to pigs over cattle. Between May 22 and 26, a total of 126,000 animals on 1,066 farms were vaccinated. Transportation of vaccinated animals was prohibited, and these animals were subsequently culled. By June 30, all vaccinated animals had been culled and buried. Raw milk from the vaccinated animals was disposed of at composting facilities, and feces was inactivated by composting. By July 18, movement restrictions in the vaccination zone were lifted.

Among these farms undergoing vaccination, infection was confirmed at 68 farms (48 cattle and 20 pig farms) after vaccination. Distributions of the duration between vaccination and detection are shown in Fig. 5 (median values for cattle and pigs were 7 and 9 days, respectively; \( P=0.039, \) Mann–Whitney test). No infection was detected 18 and 20 days after vaccination (cattle and pigs, respectively) at the farms. Given the estimated dates of clinical development on these infected farms, based on the duration of lesions [2–4, 7, 8] and farmers’ awareness, most infected farms are considered to have had their first clinical case by 7 days after vaccination. Three cattle farms were estimated to have had the first clinical development at over 7 days (range, 8–12 days) after vaccination; these farms had large populations (330–2,420 head of cattle) compared with other farms in the region. Five pig farms were considered to have had the first clinical development between 11 and 15 days after vaccination.

**Surveillance:** After the disposal of all carcasses and materials at infected farms, clinical surveillance was conducted on all susceptible animals kept on farms within the movement restriction zone. Serological surveillance was carried out for cattle and pig farms within a 3 km radius of infected farms and other related farms using liquid-phase blocking ELISA (LPBE) at the NIAH. One infected farm with 16 cattle was detected by surveillance (the final case being detected on July 4), with one cow showing clinical signs and three others (3/9) giving positive results to serological tests. Immediately after detection, a new movement restriction zone was established, and necessary control measures were taken for containment of the disease. Movement restriction was lifted after confirmation of the absence of the disease in the restriction zone by surveillance, with at least 21 days being mandatory from the time of culling of all infected and suspected animals.

After lifting the movement restrictions, clinical surveil-
The FMD epidemic in 2010 involved 292 outbreaks with approximately 290,000 animals culled over a period of two and a half months. Despite the large number of outbreaks, the major epidemic was localized to one area of Miyazaki Prefecture by the intervention measures, including vaccination. In this sense, emergency vaccination for FMD, which was used for the first time in Japan, is considered to have contributed to disease containment. However, despite effective containment by vaccination, this incident provided many lessons for future FMD control.

One of the reasons why disease control proved difficult was that FMD occurred in a densely populated livestock area. Once the FMD virus had been introduced into this high-density area, transmission between farms within a short distance (also called “local spread”) was considered highly probable because of the close proximity of farms and the frequent movement of people and commodities within the same community. In particular, after the infection of pig farms, a chain of outbreaks occurred. The excretion of a large amount of virus from infected pig farms would have led to contamination of surrounding areas, aiding spread of the disease [1]. The detailed mechanism of farm-to-farm transmission in this epidemic, including local spread, requires clarification by further epidemiological investigations.

Additionally, the rapid increase in the detection of infected farms made finding appropriate burial sites for culled animals difficult. Given the recent expansion of animal numbers on farms in Japan, from 545 pigs and 18 beef cattle per farm in 1995 to 1,437 and 38, respectively, in 2009 [9], securing a means of immediate destruction of animals became a key issue for FMD control. Considering the easy dissemination of the disease in high-density areas, disposal of culled animals by burial alone is challenging. Accordingly, a combination of alternate methods, such as incineration or rendering, should be considered for the disposal of animals at the regional or national level.

From epidemiological investigations of the initial phase of the epidemic, the FMD virus was suspected to have been introduced initially in a water buffalo (Bubalus arnee) farm located approximately 600 m from the index case. A water buffalo there reportedly displayed fever, diarrhea and a decrease in milk production at the end of March, and RT-PCR testing of samples collected on March 31 confirmed FMD virus infection. Therefore, almost one month had passed from the introduction of the FMD virus into the affected area before the index case was confirmed. From estimations of the date of clinical development, infection is presumed to have already been present on at least ten farms on April 20. This delay led to the spread of the disease in this area before countermeasures such as movement restrictions were taken. These delays are one of the main reasons for disease spread in the early stage of the epidemic. To promote early notification in future outbreaks, the government extended compensation coverage following the disease outbreak. Economic losses due to movement restrictions, preventive culling and emergency vaccination are fully compensated according to the relevant laws and regulations. On the other hand, payments are withdrawn when farmers fail to take necessary measures, including immediate notification of suspected cases.

The inquiry commission, which was established by the Ministry of Agriculture, Forestry and Fisheries to review the actions taken in response to the disease outbreaks, raised the question of the timing of emergency vaccination. In this epidemic, emergency vaccination was implemented to prevent disease spread from the affected area to surrounding areas. The decision was taken almost one month after the detection of the first FMD case, mainly on account of the delay of the stamping out operations. As a result, a huge number of healthy animals were culled because of the increased numbers of animals requiring vaccination. It is preferable for FMD-free countries to eradicate the disease solely by stamping out and movement restrictions, minimizing the number of culled animals. On the other hand, earlier vaccination enables reduction in the number of vaccinated animals, irrespective of whether the animals are later culled. Therefore, the decision to adopt emergency vaccination at the appropriate time is crucial in minimiz-
ing losses and damage, although it is often difficult to judge disease progression.

In the past, emergency vaccination has been applied for FMD control in several countries. During the 2000 FMD outbreaks in Korea and the 2001 FMD outbreaks in the Netherlands, emergency vaccination was carried out in the affected areas for disease containment [11, 12]. While vaccinated animals were later culled in the Netherlands, the vaccinated animals were not culled in Korea. Although the length of time until regaining the FMD-free status was different between the two countries, both succeeded in eradication of FMD, restraining the disease spread to limited areas. On the other hands, Uruguay in 2001 and Korea in 2010–2011 ended up converting emergency vaccination targeting limited areas into mass vaccination for the whole country during their FMD epidemics [10, 15]. It appears that emergency vaccination is not always effective for localizing FMD outbreaks in previously FMD-free countries. Furthermore, Japan and Korea succeeded in early eradication of the disease without vaccination in 2000 and 2002, respectively [16, 17]. These past events suggest that various factors are involved in successful disease containment.

Further epidemiological research should be implemented to elucidate the efficacy of various control measures such as vaccination and preventive culling in various geographical situations using the data acquired from this epidemic. Input from this research will help decision makers to take the most appropriate measures at the correct time in the future for similar crises. In addition, further technical developments would be necessary in tools supporting disease control. For example, establishment of a reliable assay system to differentiate vaccinated animals from naturally infected animals would be helpful to confirm and prevent the circulation of FMD virus in the area where vaccination is applied. A reliable rapid diagnostic system that is usable on farms would be beneficial for early detection of the disease. Further research on highly efficient vaccines and prophylactic drugs against FMD is also important for providing animal health authorities with further options concerning disease control strategies.

Despite thoughtful and intensive investigations, the route of FMD invasion into Japan has not been elucidated to date. However, given the high homology of genetic sequences between the viruses isolated in Japan and in other Asian countries, the disease may have entered Japan through the movement of people or commodities from those other countries. Considering the endemic state of FMD in Asian countries [13, 14], Japan always faces the threat of FMD outbreaks from nearby countries. The most crucial factors in minimizing damage from these outbreaks are early detection of the disease followed by immediate application of appropriate containment measures. To achieve this, well-organized emergency protocols should be formulated by animal health authorities, and awareness of FMD should be raised among the public and the livestock farming industry. In this sense, we should make full use of lessons learnt from the 2010 FMD epidemic in establishing a good response system for FMD.

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