

Local and Global Impact of Disease Outbreaks

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■ Introduction

Food and mouth disease (FMD) and Classical Swine Fever (CSF) are highly contagious diseases for pigs, and they are classified on the List A of the Organisation International des Epizooties (OIE) in Paris, France. Being a List A disease implies that every suspected case has to be investigated and once it is confirmed, the outbreak has to be notified. Both FMD and CSF are widespread in many parts of the world, and this situation poses a constant threat to countries free of the disease.

More and more it has become clear that the property of viruses and human action are important factors determining the emergence of new virus infections. RNA viruses can change rapidly and adapt to changing environmental conditions through mutations and genetic recombination and infect both human and livestock populations. However, mankind itself is a key factor. Centuries ago, urbanisation provided circumstances for rats and people to live close together and give the plague a chance to spread. Nowadays, cut down of the rain forests is presumed to be an important disturbing factor, because wild animals are forced to migrate to areas that are already inhabited by man and livestock (Garrett, 1995). These wild animals are hunted, eaten ('bush-food') and kept as pets. This situation provides the opportunity for transmission of viruses to man and livestock. Ebola virus and HIV are striking examples (Garrett, 1995; Goudsmit, 1997). Recent examples are Nipah-virus in Malaysia, West Nile virus in New York and Hepatitis E virus in the South-East Asia, the USA and Europe. Global travelling of man and transport of livestock to places all over the world has provided optimal conditions for introduction of emerging diseases to our world.

■ Foot and Mouth Disease

Foot-and-mouth disease (FMD) is a highly contagious viral disease of wild and domesticated cloven-hoofed animals (domestic species: cattle, pigs, sheep, goats, deer). A wide host range, low infectious dose susceptibility and the capacity for airborne spread over longer distances (for that matter, principally an increased risk when pigs are infected), predispose to large epidemics of FMD.

FMD is widespread in many parts of the world, in particular in South America, Africa, The Middle East and Asia. According to the information of the Office International des Epizooties (OIE) in Paris, France (weekly disease info up to 19 October 2001), the following countries had FMD outbreaks in 2001:

Argentina	Ireland	Malawi	Qatar	Turkey
Azerbaijan	Israel	Malaysia	Saudi Arabia	Great Britain
Brazil	Kazakhstan	Mali	South Africa	Northern Ireland
Eritrea	Kuwait	Mongolia	Swaziland	Uruguay
France	Kyrgyzstan	Netherlands	Taiwan	Zimbabwe

FMD outbreaks in 1997 in Taiwan (which had been FMD-free since 1929), in Japan in 2000 (which had been FMD-free since 1928), in the Republic of Korea (ROK) in 2000 (which had been FMD-free since 1934), and in the United Kingdom in 2001 (which had its last reported outbreak of FMD in the Isle of Wight in 1981) show the importance of remaining vigilant. In these countries, the diagnosis of FMD is often difficult, because it is an exotic disease for decades, unfamiliar to both farmers and veterinarians.

FMD outbreaks can have a devastating effect upon the agricultural economies of developed, and particularly FMD-free countries, due to the cost of disease control measures and serious constraints on international meat and livestock trade. Furthermore, it becomes clear that not only the agriculture industry but also the tourist industry can be severely struck by FMD outbreaks in developed countries.

In 1997, between March and July, a devastating FMD-epidemic occurred in Taiwan (Yang et al., 1999). A total of 6,147 pig farms with more than 4 million pigs became infected, roughly 38% of Taiwan's entire population of pigs. Except for two major cities (Taipei and Keelung), the whole of Taiwan was declared an FMD-infected zone. A policy of depopulating each infected farm and vaccinating all the pigs on farms at high risk was adopted immediately after each farm outbreak of FMD was confirmed. To give an idea about the huge rate of spread between farms: within the first week after detection of the first case,

infection was identified in 217 pig herds, and after two weeks in more than 1000 pig herds. Four major factors were indicated to be responsible for the rapid spread of the epidemic in Taiwan: the inability of the government to shut down the livestock auction markets; the long delays before infected farms could be depopulated in the eradication program; the high density of pig farms; and the inadequate quantity of vaccines available during the emergency. The financial cost of the epidemic was estimated at US\$ 379 million, including indemnities of pigs slaughtered, cost of vaccine, carcass disposal and environmental protection, miscellaneous expenses (disinfectants, boots, coveralls etc.) and loss of market value. In addition to the direct economic losses, the pig industry and related industries continued to suffer severe financial losses. As a result of the ban on the export of pork to Japan, an estimated loss of US\$ 1.6 billion was incurred by the Taiwan pig industry. Among other businesses affected, feed mills, the pharmaceutical industry, meat packers for exportation, farm equipment manufacturers and suppliers, livestock markets, and the transport industry were the hardest hit. Over 65,000 jobs were lost in these affected businesses during and after the epidemic.

Between 25 March and 15 April 2000, fifteen outbreaks of FMD were reported in the ROK in three provinces (Ozawa et al., 2001). All involved cattle farms. ROK was able to contain the FMD outbreaks successfully through the prompt and efficient implementation of appropriate control measures including movement restrictions, stamping-out and emergency vaccination. These efforts have undoubtedly been a major factor in limiting the number of outbreaks to just 15 (Garner, 2000). Movement restrictions were lifted, after extensive serological surveillance, on 19 July 2000. Vaccination of susceptible livestock within the protection zones was completed in August 2000. During the first and second rounds of booster vaccinations, a total of 860,700 and 661,770 animals were vaccinated, respectively. Vaccinated animals, except for finishing pigs to be slaughtered immediately, were permanently marked by ear punching (pigs) and branding (cattle, goats, and deer). Cattle were the only animals affected during the outbreaks in the ROK. However, it was shown that pigs were susceptible to the Korean virus isolate. Despite the fact that the FMD-epidemic was fairly limited, the pig industry was severely damaged because its major export market (Japan) was closed. It was anticipated that the pig industry in ROK had to shrink drastically, in order to survive. ROK regained its FMD-free status on 19 September 2001, nearly 1.5 years after detection of the first outbreak.

On 20 February 2001, the United Kingdom was shaken by the announcement that FMD had reoccurred on the mainland of the UK after 33 years of absence. At the time of writing this paper (end of October 2001), it seems that the epidemic is coming to a halt with 2030 confirmed outbreaks, the last outbreak dated 30 September 2001. The first case of FMD was confirmed on 20 February in Essex, but the source was traced to a pig farm in Heddon on the Wall in Northumberland. Swill feeding was implicated as the source of infection.

Further cases, widely spread across England, Wales and Scotland, plus a small number in Northern Ireland, came to light quickly thereafter. As at October 24, 9,591 farms with 3,915,000 animals (600,000 cattle; 3,173,000 sheep; 139,000 pigs; 3,000 goats; 1,000 deer and 200 other animals) in the UK have had their livestock compulsorily slaughtered, including 2,030 where the disease has been diagnosed. Including the Livestock Welfare Disposal scheme for unmarketable livestock (1,819,491 animals), a staggering 5.7 million animals have been slaughtered (source: DAFRA, 2001). The impact on other livestock farmers from the dislocation to their normal business has also been very severe: 139,000 farms in designated Infected areas were subject to tight restrictions preventing movement of animals except for slaughter. There has also been a loss of direct sales (such as farm shops and farmers' markets), and of non-farming incomes, such as farm tourism. There has been a large drop in demand for farming support services, notably haulage, and livestock markets have been closed entirely.

Media coverage of the efforts to eradicate FMD, particularly of the culling and disposal of livestock, was dramatic. This, together with the closure of almost all footpaths at the start of the epidemic, convinced many prospective tourists from both home (up to 25% reduction) and abroad (up to 10% reduction) that Britain's countryside was closed and encouraged them to turn elsewhere for their holidays (Rural Task Force, 2001). There are indications that more money has been lost to the UK economy as a result of the effect of the outbreak on tourism than as a result of its effect on agriculture, because the drop in visitors reduced trade for a wide range of rural businesses – not just hotels and visitor attractions - but pubs, shops, filling stations etc. Losses extended to other industries, including suppliers to the farming industry (livestock hauliers and makers of farm machinery), fishing, shooting and the horse business; makers of outdoor clothing, cycle manufacturers, guidebook publishers, theatres and language schools etc.

The impact of FMD on the economy as a whole have been estimated for the UK in 2001 ranging from 0.2 – 0.8% of GDP (US\$ 2.3 to 9.0 billion), Tourism taking a share of US\$ 2.9 to 4.3 billion.

■ Classical Swine Fever

Classical Swine Fever (CSF, also called Hog Cholera, European Swine Fever) is probably the economically most important viral infectious disease of domestic pigs. After implementation of strict control measures, several countries, including Australia, Canada, New Zealand, United States of America (USA), and some member states of the European Union (EU), succeeded in eradicating the virus. In most other parts of the world with significant pig production CSF virus is present, causing substantial economic damage

(Edwards et al., 2000). Natural hosts of CSF virus (CSFV) are not only domestic pigs but also wild boar.

The occurrence, density and behaviour of wild boar populations are important for the epidemiology of CSF. The population of wild boar appears to have increased all over Europe and the present population in EU member states is estimated 800,000 - 1,000,000. CSF is endemic in wild boar and represents a permanent virus reservoir that poses a constant threat to domestic pigs. In recent years CSF was observed in Western European countries in wild boar in Austria, Switzerland, Germany, France and Italy. However, also in Central and Eastern European countries that surround the EU, CSF is presumed to be endemic in wild boar (monitoring data are often not available).

In Central and South America, The Caribbean, South East Asia, and Central and Eastern European countries, CSF is controlled by vaccination. This implies a continuing cost as well as restrictions on trade with CSF-free areas. Nevertheless a policy of consistent and systematic prophylactic vaccination in endemic situations may ultimately lead to a favourable starting point for a non vaccination policy and the eradication of the virus. After the cessation of general vaccination, eventual local outbreaks of residual field virus must be dealt with by strict measures to ensure prevention of virus spread and eradication of the virus. Progress towards global eradication is very slow, determined in many countries by economic and social factors: high proportion of 'backyard' pigs, a highly mobile pig population sold via auction markets with lots of contacts, and an inadequate level of vaccination. In developed countries progress is governed by the technical difficulties of dealing with infection among wild boar, and the challenges of large livestock units and high pig population densities.

In recent years, massive outbreaks were observed in domestic pigs in EU member states in areas with a high pig and farm density: Germany, Italy, Spain, The Netherlands. In these countries, eradication measures are based on stamping out (depopulation) of infected herds and pre-emptive slaughter of possibly infected contact and/or neighbouring herds, movement restrictions and other zoo-sanitary measures. Especially in areas with dense pig populations, very high numbers of pigs had to be destroyed in the course of the eradication measures.

In 1990, a CSF epidemic in 4 different provinces in Belgium in areas with a high pig concentration caused serious veterinary, budgetary, economic and social problems (Vanthemsche, 1996). A total of 113 herds got infected, and 1.2 million pigs were destroyed before the virus was eradicated. Only in the end of the epidemic, pre-emptive slaughter was executed (Miry et al., 1991). The total cost of this epidemic amounted more than US\$ 280 million.

In October 1993, in the province of West Flanders a new CSF-outbreak occurred in Wingene, in the same area as in 1990. Six more outbreaks were located in the protection zone. By the end of 1993, the West Flanders part of the epidemic was under control. In January 1994, CSF broke out in the province of Eastern Flanders in a farm 15 km east of the epicentre of Wingene. Subsequently a 47 further outbreaks occurred. Control measures were finally lifted on 2 January 1995. From the beginning of the epidemic, pre-emptive slaughter of contact and neighbourhood herds was executed. During the 1993-94 epidemic, a total of 797,625 pigs (308,580 pigs in sanitary measures, and 435,291 pigs in market support operations) were destroyed. The total cost of all operations was US\$ 120.5 million.

The most recent and probably most costly epidemic started at the end of 1996 in a pig herd in Western Germany due to illegal swill feeding (Elbers et al., 1999). CSFV was subsequently spread to several regional pig farms and presumably from Germany to The Netherlands through a contaminated transport truck, and from The Netherlands to Spain, Italy and Belgium. Once an outbreak becomes an extensive epidemic, as happened in 1997, the costs of control begin to escalate, and the practicality of imposing strict control measures can become increasingly difficult. In Table 1, the number of pigs slaughtered on high-risk farms, together with the much larger numbers needing to be removed for welfare reasons due to the standstill on pig movements for a prolonged period is shown. Losses calculated for the CSF-epidemic in 1997-98 in the Netherlands amounted US\$ 2.34 billion (Meuwissen et al., 1999): US\$ 1.32 billion direct costs (depopulation, welfare slaughter, organisation eradication etc.), US\$ 228 million consequential losses farms (idle production, supply problems, re-population), and US\$ 596 million consequential losses of related industries (traders, feed suppliers, breeding organisations).

Table 1. Number of pigs slaughtered from infected and contact herds, and numbers removed for welfare reasons, during the 1997 CSF-epidemic in the EU (source: Edwards et al., 2000)

Member State	No. of Outbreaks	Pigs killed in infected and contact herds	Pigs removed for welfare reasons
Germany	46	41,000	62,494
Netherlands	424	682,000	8,111,118
Italy	44	3,000	0
Spain	78	90,000	621,798
Belgium	8	60,000	35,126
Total	611	876,000	8,830,536

The 1997-98 CSF epidemic in EU-member states has had a huge impact on the pig and related industries. During and after the epidemic, a lot of pig farmers went out of business, introducing social problems in the countryside. The Dutch and Belgium government jumped at the occasion to start an obligatory shrinkage of the pig industry by 20-25% (selling out farmers).

■ Nipah virus

Between late 1998 and 1999, the spread of a new disease of pigs, characterised by a pronounced respiratory and neurological syndrome, sometimes accompanied by the sudden death of sows and boars, was recorded in pig farms in peninsular Malaysia (Nor et al., 2000). The disease appeared to have a close association with an epidemic of viral encephalitis among workers on pig farms. Attention was focused on the mysterious pig disease as numerous and stringent measures used to control the disease, first thought to be caused by Japanese encephalitis virus, failed to control the incidence of the viral encephalitis epidemic in the pig farm workers. A new virus named Nipah virus, named after the village Sungai Nipah in the state of Negeri Sembilan from which the virus was first isolated from a human case, belonging to the *Paramyxoviridae* family, was discovered and later confirmed to be the agent responsible for disease in both humans and pigs. Between October 1998 and May 1999, a total of 265 cases of viral encephalitis were recorded in humans involved in pig farming activities; a total of 105 of these cases resulted in death.

Nipah virus is closely related, but distinct from, the Hendra virus, a recently emerged zoonotic paramyxovirus responsible for fatal disease in horses and humans in Queensland, Australia (Murray et al., 1995). The virus is relatively unstable in vitro and can be readily disinfected with common detergents. Pigs, dogs and humans were infected with the virus during the outbreaks in peninsular Malaysia. Other animals such as cats, horses and goats were infected, but only if exposed to infected pigs. Recently, it has become clear that there is a reservoir of Nipah virus in fruit- and insectivorous bats (flying foxes) (Johara et al., 2001), species of which are the probable natural host of Hendra virus in Australia.

The Nipah virus epidemic is believed to have originated in the State of Perak and moved south to the States of Negeri Sembilan and Selangor. The mode of transmission of the virus among pig farms within and between States of Malaysia, was the movement of pigs by very active pig trade, which is normal practice in peninsular Malaysia. Evidence has shown that farms that did not receive animals suspected of infection remained free of infection during the testing and surveillance program, although such farms were located immediately adjacent to an infected farm. Transmission between farms in

farming communities was attributed to several possible means, for example, sharing boar semen and transmission by dogs and cats. It is suspected that dogs and cats were infected with urine and excreta from lorries carrying affected pigs, and subsequently introduced the virus to uninfected farms.

The disease was observed to spread rapidly among pigs on infected farms. Based on observations of the natural infection, the clinical signs varied according to the age of the pigs. Sows were noted to present primarily the neurological syndrome (muscle spasms, agitation, apparent pharyngeal muscle paralysis), while in fattening pigs, the respiratory syndrome (fever, rapid and laboured respiration, harsh non-productive barking cough) predominated. However, clinical disease could also be very subtle, showing asymptomatic signs.

With the discovery of the aetiology of the pig disease, an immediate 'stamping out' policy was instigated to cull all pigs in the outbreak areas. A total of 901,228 pigs from 896 farms were destroyed in the infected areas from 28 February to 26 April 1999. The culling of pigs in these areas successfully controlled the human epidemic in States of Negeri, Perak and Selangor. The culling program ceased when an ELISA was made available to identify infected farms in a national swine testing and surveillance program. The cross-reactivity between Nipah and Hendra viruses facilitated the early application of an indirect ELISA for screening. Later, an indirect IgG ELISA, using Nipah antigen, was developed in Malaysia and this test was used for a second round of testing and surveillance, launched on 21 April 1999. A total of 889 farms were tested nation-wide between 21 April and 20 July 1999. Of these, 50 farms were found sero-positive. Farms recorded sero-positive were considered infected and a total of 172,750 pigs from these farms were destroyed at the end of July 1999.

Currently, a control program is being developed to provide continued monitoring of all pigs entering an abattoir.

The Nipah virus outbreak has had a significant impact on the pig industry in peninsular Malaysia, with a marked reduction in the standing pig population (SPP) and the total number of farms. By 31 July 1999, the total SPP was reduced from 2.4 million to 1.32 million, and the number of farms was reduced from 1,885 to 829.

The apparent relationship between Hendra and Nipah virus created some confusion, and subsequently some countries considered pork from regions with a history of Hendra virus as posing a potential health threat. Queensland Australia came under intense scrutiny, and in May 1999 one market chose to ban the importation of all pig products from Queensland. In order to maintain access to overseas markets, it was necessary to provide evidence that the Queensland commercial pig population was free of Hendra and Nipah viruses.

A serological survey supported the case that commercial pigs in Queensland were free of Hendra and Nipah virus (Black et al., 2001).

■ Hepatitis E virus

Hepatitis E virus (HEV) is the leading cause of enterically transmitted non-A, non-B Hepatitis in humans in much of the developing world and can be considered an emerging infection in industrialised countries. Transmission is thought to be primarily by the faecal-oral route, and waterborne epidemics are characteristic of HEV. Clinical disease due to HEV infection is rarely diagnosed in industrialised countries and most cases of HEV infection in industrialised countries occur in people who have travelled to regions where the disease is endemic. Clinical cases occur predominantly in developing countries in southeast and central Asia, the Middle East, parts of Africa, and Mexico. However, sporadic cases of acute HEV in people in the USA and other industrialised countries have recently been reported. Clinical attack rates are the highest among young adults. In younger age groups, infections are more asymptomatic. Although the mortality rate is usually low (0.1-0.6%), the illness may be particularly severe among pregnant women, with mortality rates reaching as high as 25%. To date no specific treatment is available for HEV. Ensuring a clean water supply remains the best preventive strategy.

There is evidence that animals may act as natural hosts of HEV. Wild-caught rodents, wild-caught monkeys such as rhesus, bonnet, or langur monkeys, marmosets and tamarins were positive for anti-HEV antibodies and/or presence of viruses in sera or stools (Smith, 2001). However, it is not clear if the animals had been infected by animal or human viruses.

What is more interesting and also more disturbing is the demonstration of HEV in certain domestic animals. Anti-HEV has been detected in domestic cattle from Turkmenistan and Ukraine.

In 1997, a novel virus closely related to human HEV was discovered in pigs, characterised, and designated swine HEV (Meng et al., 1997). The swine HEV and human HEV strains from the USA share > 97% amino acid identity at two important sections of the gene coding for non-structural proteins. In Taiwan, Hsieh et al. (1999) isolated an other new strain of swine HEV from a pig. This Taiwanese strain of swine HEV shares 97.3% nucleotide sequence identity with a human strain of HEV isolated from a retired farmer in Taiwan, but was distinct from the USA strain of swine HEV. These findings suggests the possibility of zoonotic HEV infection.

The exact role of swine in the transmission of HEV remains unclear. Serological surveys done to date suggest that swine HEV is widespread in the midwestern

US swine population (Meng et al., 1997), as well as in other regions of the world (Smith, 2001): Australia, Germany, Nepal, Vietnam, Taiwan, Korea, Canada (Quebec and Ontario) and recently New Zealand (Garkavenko et al., 2001) A recent study in the Netherlands indicated that in 22% of farms in a sample of 115 swine farms swine HEV was detected (van der Poel et al., 2001). HEVs from swine in the Netherlands were clustered genetically in at least two groups, together with European and American isolates from swine as well as humans. The swine HEVs isolated in the Netherlands were genetically closely related with HEVs from humans, although so far viruses identical to these swine HEVs have not been found in humans. Experimental infection of pigs with HEVs recovered from a pig and a human showed comparative pathogenesis (Halbur et al., 2001). Because swine can be infected with human strains of HEV and because human HEV RNA has been detected in swine sera and faeces, it is highly possible that swine could contaminate water supplies with the virus and/or that transmission of virus could occur during high-risk operations of blood contamination such as pig slaughtering. Raw pork from pigs infected with human HEV could lead to cross-contamination of other foods, and inadequately cooked pork could be a vehicle for foodborne HEV. Furthermore, swine manure could be an important source of HEV contamination for irrigation water. In addition, if irrigation water is used as drinking water by wild and domestic animals, there is a possibility that the water will be fecally contaminated by the animals.

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