Foot and Mouth Epidemic Reduces Cases of Human Cryptosporidiosis in Scotland

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In Scotland, rates of cryptosporidiosis infection in humans peak during the spring, a peak that is coincident with the peak in rates of infection in farm animals (during lambing and calving time). Here we show that, during the outbreak of foot and mouth disease (FMD) in 2001, there was a significant reduction in human cases of cryptosporidiosis infection in southern Scotland, where FMD was present, whereas, in the rest of Scotland, there was a reduction in cases that was not significant. We associate the reduction in human cases of cryptosporidiosis infection with the reduction in the number of young farm animals, together with restrictions on movement of both farm animals and humans, during the outbreak of FMD in 2001. We further show that, during 2002, there was recovery in the rate of cryptosporidiosis infection in humans throughout Scotland, particularly in the FMD-infected area, but that rates of infection remained lower, though not significantly, than pre-2001 levels.

Cryptosporidium is a zoonotic pathogen that is increasingly being recognized as a major cause of diarrheal disease worldwide [1]. *C. parvum* is the species that dominates infection in humans. In immunocompetent individuals, it causes a self-limiting (10–25 d) disease with symptoms of diarrhea, nausea, and low-grade fever with occasional vomiting, whereas, in immunocompromised individuals, it can lead to chronic disease [2]. From human-feeding studies, the infective dose of *C. parvum* has been found to be extremely low [3–5], with ID_{50} values ranging from ∼2000 to as few as 12 oocysts [6].

Cryptosporidium is regarded as a waterborne microbial pathogen [6] because it is found in surface and drinking waters and has been implicated in a number of outbreaks associated with contaminated drinking water (e.g., 6 outbreaks in England during 1994–1999, in each of which 6–575 cases of illness were reported [7], and 1 outbreak in Milwaukee during 1993, in which >400,000 cases of illness were reported [8]). Cryptosporidiosis in humans is also associated with foreign travel, food, and direct contact with infected humans, farm animals, and wild animals [1, 7, 9]. It comprises 2 main genotypes [10]: genotype 1 (human type), which occurs virtually exclusively in infected humans, and genotype 2 (animal type), which occurs in farm animals as well as in humans.

In Scotland, rates of cryptosporidiosis infection in farm animals peak during the spring, a peak that is coincident with lambing and calving time [7]. Similarly, rates of infection in humans peak during the spring, a peak principally comprising infections due to the animal genotype, with a smaller peak in late summer/early autumn comprising infections due to either genotype. In the United Kingdom, the outbreak of foot and mouth disease (FMD) during 2001 began in early February, and Scotland was not declared to be free of the disease until 11 September 2001. It has been reported that, in northern England, there was a significant reduction in cases of human cryptosporidiosis infection during the outbreak of FMD [11, 12]. In Scotland, the FMD epidemic was contained within the south, in the regions of Dumfries and Galloway and the Borders, where ∼31% of the 2.9 million sheep and ∼17% of the 0.6 million cattle were slaughtered—whereas, in the FMD-free area of Scotland, <0.02% of the 6.2 million sheep and <0.5% of the 1.4 million cattle were slaughtered [13].

Restrictions on both the transport of animals and access to the countryside for humans were imposed on 23 February 2001 and were in place throughout Scotland from spring to summer/autumn. In Scotland during 2001, rates of cryptosporidiosis infection in humans fell by 34%, compared with those during the previous year [14]. Here we discuss both the temporal reduction in rates of cryptosporidiosis infection in humans in the FMD-infected area of Scotland and how this reduction compares with that in the remainder of Scotland.

Methods. Data on weekly rates of cryptosporidiosis infection in humans, for each of the regions in Scotland, during 1994–2002, were obtained from the Scottish Centre for Infection and Environmental Health [14]. Data on monthly rates of infection in cattle and sheep, during 1994–2002, were obtained from the Veterinary Laboratories Agency, Addlestone,

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Received 24 September 2002; accepted 21 March 2003; electronically published 8 August 2003.

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The Journal of Infectious Diseases 2003; 188:783–6

0022-1899/2003/18805-0020$15.00

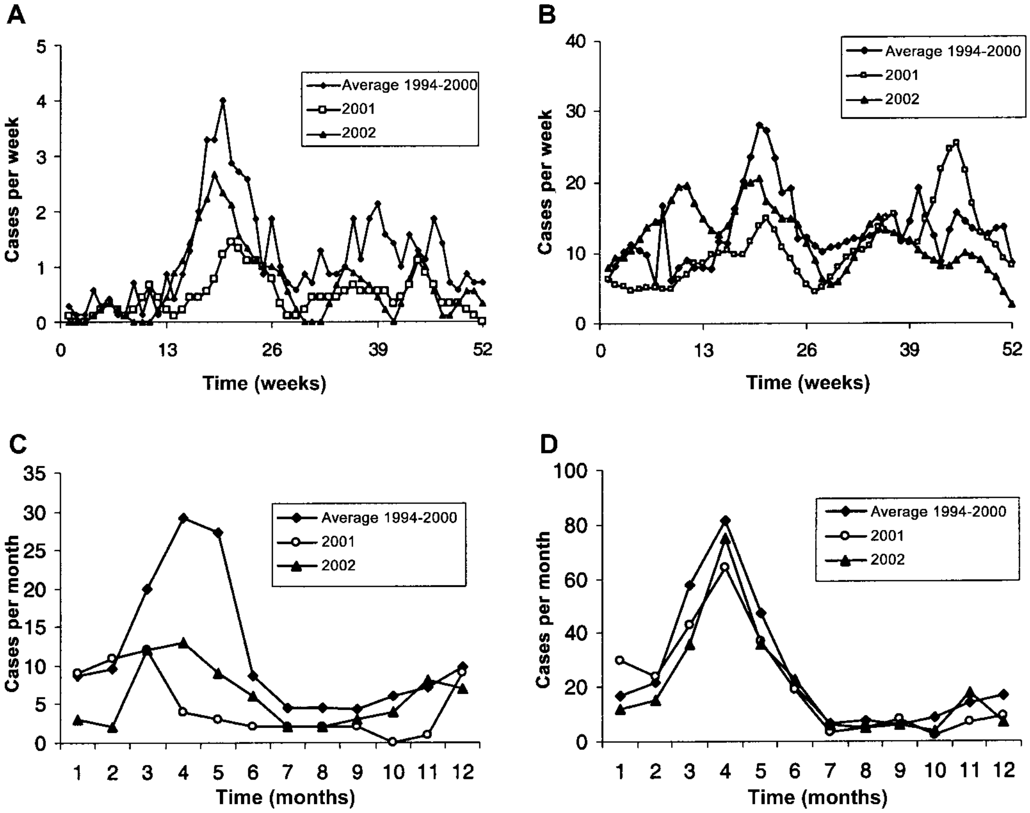

Figure 1. Reports of cryptosporidiosis in humans *(A)* and cattle *(C)* in FMD-infected areas of Scotland and in humans *(B)* and cattle *(D)* in FMD-free areas of Scotland.

United Kingdom. Data sets on infection both in humans and in animals were collated into Microsoft Excel and were then merged into a data set for the FMD-infected area (southern Scotland, comprising Dumfries and Galloway and the Borders) and into a data set for the FMD-free area (the remainder of Scotland). The data for the FMD-free area during 1998 were omitted from analysis because of a large outbreak of cryptosporidiosis in the Greater Glasgow area.

The t test was used to independently determine whether, during the outbreak of FMD, there was a significant reduction in the rate of cryptosporidiosis infection in humans in the FMD-infected and FMD-free areas of Scotland: $t_{n-1} = (y - \bar{x})/s\sqrt{1 + (1/n)}$, where y is the number of cases during the outbreak (which, in 2001, occurred during weeks 13–38), s is the SD, $\bar{x}$ is the average of the preceding 7 years, and n is the number of years. To determine whether there was a reduction during the remaining weeks of 2001, data for that period were also compared with the data for the preceding 7 years. To determine whether any reductions that were found persisted, the data on infection during 2002 were also analyzed by the t test. The t test was used to compare the data on annual cryptosporidial infection in cattle, during both 2001 and 2002, with the data on cryptosporidial infection in cattle during 1994–2000 (data for the FMD-infected area and those for the FMD-free area of Scotland were independently compared).

Results. During 2001, rates of cryptosporidiosis infection in humans fell both in the FMD-infected and the FMD-free areas of Scotland, by 60% and 19%, respectively (figures 1*A* and 1*B*). During the actual outbreak (weeks 13–38 of 2001), there was a significant reduction in cases of human cryptosporidiosis infection in the FMD-infected area ($t_6 = -2.98$; $P = .012$); although there also was a reduction in the FMD-free area, it was not significant ($t_5 = -1.86$; $P = .061$). During weeks 1–12 and 39–52, although there was a reduction in cases of human cryptosporidial infection in both the FMD-infected and FMD-free areas, it was not significant (FMD infected, $t_6 = -1.44$; $P = .100$; and FMD free, $t_5 = -0.10$; $P = .461$). In 2002, both the FMD-infected and FMD-free areas showed an increase in cases of infection, compared with 2001 (40% and 13%, respectively), but cases of infection were still below the 1994–2000 average, although not significantly (FMD infected, $t_6 = -1.88$; $P = .054$; FMD free, $t_5 = -0.46$; $P = .333$).

During 2001, rates of cryptosporidiosis infection in cattle fell significantly (figures 1*C* and 1*D*) in the FMD-infected area ($t_6 = -2.70$; $P = .018$), compared with no significant decline in the FMD-free area ($t_6 = -0.88$; $P = .206$). During 2002, rates of cryptosporidiosis infection in the FMD-infected area partially recovered but still remained significantly low ($t_6 = -2.27$; $P = .032$).

Discussion. It has been hypothesized that the effects of the FMD epidemic caused the reduction in cases of cryptosporidiosis infection in humans throughout Scotland and particularly in the FMD-infected area. Evidence supporting this claim includes the following: restrictions on movement of farm animals (reducing mixing and hence reducing rates of infection in animals); fewer young farm animals during the spring, which release the highest loads of the organism into the environment (as a result of the slaughter of both pregnant adults and young farm animals); reduction in cases of cryptosporidial infections in farm animals in the FMD-infected area of Scotland and fewer members of the public visiting the countryside, because of restrictions meant to control FMD, a decrease resulting in a reduction in exposure to *Cryptosporidium* oocysts via direct contact with farm animals and their feces. In addition, it is not surprising that rates of human cryptosporidial infection were reduced significantly by the outbreak of FMD in the FMD-infected area, because this part of Scotland is predominantly rural and contains no cities, and because, on average, 46% of infections coincide with the peak in lambing and calving, during the second quarter of the year—whereas, for the remainder of Scotland, which contains all of the large population centers, only 35% of infections occur during the second quarter of the year. Particularly during the latter half of the year, this FMD-free area of Scotland also has higher background levels of cryptosporidiosis infection in humans, which could largely comprise the human genotype. There are, for Scotland, no genotype data available to support this statement, but it does agree with the available genotype data for England and Wales [7].

Other possible explanations for the reduction in cases of cryptosporidiosis infection in humans during 2001 include the following: lack of rain, hence a reduction in runoff of pathogens to watercourses (precipitation in the United Kingdom during 2001 was lower than the average during 1994–2000, but this was not significant [$t_6 = 1.93$; $P = .101$] [15]); chance (but rates of cryptosporidiosis infection in humans were lower in both the FMD-infected and FMD-free areas of Scotland than at any time during the previous 7 years); improvements in water treatment (but this would not have stopped infection by direct contact with farm animals or their feces and should have shown a trend throughout the year if human sewage was the source); and increased immunoprotection of the population (but there is no obvious reason why this would have occurred). Hence, reiterating the fact that the peak in rates of cryptosporidiosis infection in humans in Scotland is coincident with the peak in rates of infection in farm animals, the genotype data available for England and Wales demonstrate that spring and summer infections are dominated by the animal genotype [7] and that the percentage reduction in cases of cryptosporidiosis infection in humans in Scotland was much higher for the FMD-infected area than for the FMD-free area; therefore, the only plausible explanation for the reduction in cases of cryptosporidiosis infection in humans in Scotland during 2001 is the effects of the FMD epidemic.

Because of the relaxation of restrictions on movement of people and animals throughout Scotland, the recovery of the rate of cryptosporidiosis infection in humans, during 2002 in Scotland is not surprising. However, the numbers of infections in humans are still lower than average, although not significantly. What is surprising is that, in the FMD-infected area, the numbers of cryptosporidiosis infections in cattle are still significantly below pre-2000 numbers. This could be due to either underreporting, since cryptosporidiosis is a nonnotifiable disease, or a reluctance by farmers to encourage visits to their farms unless such visits are deemed essential, because of the perceived potential risk of another outbreak of FMD. This study has demonstrated that the perturbation of an epidemic of an infectious disease in one species can have important effects on the rate and pattern of infection of another infectious disease in another species.

Acknowledgments

We would like to thank the Veterinary Laboratories Agency, Addlestone, Surrey, United Kingdom, for providing the data on cryptosporidial infection in cattle.

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