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Space–time interaction as an indicator of local spread during the 2001 FMD outbreak in the UK

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Abstract

During the 2001 FMD outbreak in the UK, decisions on the level of implementation of control measures were supported by predictive models. Models were mainly used as macro-level tools to predict the behaviour of the disease in the whole country rather than at the local level. Here we explore the use of the magnitude and characteristics of the space–time interaction as an indicator of local spread and, indirectly, of the effectiveness of control measures aimed at reducing short-range transmission during the course of a major livestock disease epidemic.

The spatiotemporal evolution patterns are described in the four main clusters that were observed during the outbreak by means of the hazard rate and space–time *K*-function ($K(s,t)$). For each local outbreak, the relative measure $D_0(s,t)$, derived from $K(s,t)$, which represents the excess risk attributable to the space–time interaction was calculated for consecutive 20-day temporal windows to represent the dynamics of the space–time interaction.

The dynamics of the spatiotemporal interaction were very different among the four local clusters, suggesting that the intensity of local spread, and therefore the effectiveness of control measures, markedly differed between local outbreaks. The large heterogeneity observed in the relative impact of being close in time and space to an infected premises suggests that the decision making in relation to control of the outbreak would have benefited from indicators of local spread which could be used to complement global predictive modelling results. Despite its limitations, our results suggest that the

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real-time analysis of the space–time interaction can be a valuable decision support tool during the course of a livestock disease epidemic.

Keywords: Foot-and-mouth disease; Disease transmission; Spatiotemporal epidemiology; Space–time *K*-function

1. Introduction

On 20th February 2001, foot-and-mouth disease (FMD) was confirmed in the UK for the first time in 34 years. Almost 1 year later, on 14th January 2002, after a cumulative total of 2030 cases and the culling of some 6 million animals, the last county (Northumberland) was declared FMD free (Anderson, 2002). Following confirmation of the disease in pigs in an abattoir in Essex, control measures aimed at decreasing the effective range of FMD transmission (movement restrictions) and to reduce the infectious period (culling of infected premises) were put in place (Anderson, 2002; Gibbens et al., 2001). For the first time in a major FMD outbreak, control strategies were driven by predictive models, which, though adopting different approaches, shared the same objectives, were built using the same data, and reached fairly similar conclusions (Haydon et al., 2004; Kao, 2002). The predictive models developed (Ferguson et al., 2001a,b; Keeling et al., 2001; Morris et al., 2001) have been described and discussed extensively elsewhere (Kao, 2002; Woolhouse, 2003).

During the outbreak, models were mainly used to predict the size and duration of the epidemic aggregated across the whole country rather than for simulating transmission in well–defined local areas. These global predictions appeared in general to be accurate and robust and the implementation of control policies informed by them was effective to achieve eradication of FMD by the end of September 2001 (Kao, 2002). However, during and after the outbreak, the appropriateness of using global models to inform local decisions was criticized. Based on the study of local events in selected areas, Honhold et al. (2004a,b) and Taylor et al. (2004) suggested that the relative role of local spread may have been overestimated, resulting in an unjustified high number of premises being pre-emptively culled in some areas (Honhold et al., 2004a,b; Taylor et al., 2004). It is not surprising that local scale studies identify exceptions to the most likely general behaviour predicted by global models and, while these findings do not provide any evidence against the use of global models, the apparent contradictions highlight the fact that when the study of an epidemic is approached at an aggregated scale some detail will inevitably be lost. Woolhouse (2003) emphasized that "*an understanding of dynamics of the global epidemic is not a substitute for local decision making*". The monitoring of local or smaller scale events during an epidemic should complement large-scale modelling and assist in local decision making by revealing local differences in its behaviour. This information may contribute to a better management of the outbreak by informing the adaptation of the global policy to local circumstances.

In this paper, we present a description of the 2001 FMD epidemic in the UK from the local perspective. For the main geographically separated outbreaks that were observed during the course of the epidemic (Devon, Settle, South Penrith and Cumbria-Borderlands) we present a description of the temporal and spatiotemporal patterns of disease occurrence.