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Evaluating the effectiveness of early vaccination in the control and eradication of equine influenza—A modelling approach

M.G. Garner[a,*], B. Cowled[a], I.J. East[a], B.J. Moloney[b], N.Y. Kung[c]

[a] Office of the Chief Veterinary Officer, Department of Agriculture, Fisheries and Forestry, GPO Box 858, 18 Marcus Clarke St, Canberra, ACT 2601, Australia
[b] NSW Department of Primary Industries, Locked Bag 21, Orange, NSW 2800, Australia
[c] Queensland Primary Industries and Fisheries, LMB No 4, Moorooka, QLD 4105, Australia

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ABSTRACT

In August 2007, Australia which had previously been free of equine influenza, experienced a large outbreak that lasted approximately 4 months before it was eradicated. The outbreak required a significant national response by government and the horse industries. The main components of the response were movement controls, biosecurity measures, risk-based zoning and, subsequently, vaccination to contain the outbreak. Although not initially used, vaccination became a key element in the eradication program, with approximately 140 000 horses vaccinated. Vaccination is recognised as a valuable tool for managing EI in endemically infected countries but there is little experience using it in situations where the objective is disease eradication. Vaccination was undoubtedly an important factor in 2007 as it enabled movements of some horses and associated industry activities to recommence. However, its contribution to containment and eradication is less clear. A premises-level equine influenza model, based on an epidemiological analysis of the 2007 outbreak, was developed to evaluate effectiveness of the mitigation strategies used and to investigate whether vaccination, if applied earlier, would have had an effect on the course of the outbreak. The results indicate that early use of strategic vaccination could have significantly reduced the size of the outbreak. The four vaccination strategies evaluated had, by 1 month into the control program, reduced the number of new infections on average by 60% and the size of the infected area by 8–9%. If resources are limited, a 1 km suppressive ring vaccination around infected premises gave the best results, but with greater vaccination capacity, a 3 km ring vaccination was the most effective strategy. The findings suggest that as well as reducing clinical and economic impacts, vaccination when used with biosecurity measures and movement controls could play an important role in the containment and eradication of equine influenza.

1. Introduction

Equine influenza (EI) is a highly contagious respiratory disease of horses. It is associated with high fever, coughing, nasal discharge, inappetance and depression (Geering et al., 1995). These effects are important in performance horses, particularly racehorses, and outbreaks may result in movement restrictions, closure of events and race meetings (Animal Health Australia, 2007). Prior to 2007, Australia had been free of this disease, but in August 2007 experienced a large outbreak that lasted approximately 4 months before it was eradicated. It had a major impact on both the racing and recreational horse sectors. Although infection was limited to parts of two states — New South

* Corresponding author. Tel.: +61 2 62725369; fax: +61 2 62724533.
E-mail address: graeme.garner@daff.gov.au (M.G. Garner).

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Wales (NSW) and Queensland (Qld), it involved a significant national response involving the Australian federal government, all state and territory governments and the horse industries.

The objective of the national EI response was to contain the disease with a view to eradication. The key components of the control program, which began on 25 August 2007, were movement controls, biosecurity measures, and risk-based zoning and, subsequently, vaccination to contain the outbreak. The field response was guided by the AUSVETPLAN Disease Strategy for Equine Influenza (Animal Health Australia, 2007). Policy decisions were made by the government-industry National Management Group (NMG) with technical advice from the Consultative Committee on Emergency Animal Diseases (CCEAD). By the time the last case occurred (25 December 2007), there had been 10 651 infected premises reported with an estimated 76 000 horses infected, and 140 000 horses had been vaccinated (Cowled et al., 2008).

The cost of disease eradication including movement controls, vaccination, surveillance and industry support programs was more than $AUD360m, with $AUD98m in direct response costs and $AUD256m in Australian government assistance (EI Epidemiology Support Group, 2009). Indirect and flow-on costs to industry are estimated to have been more than $AUD1billion (Messara, 2008).

Vaccination was not included as part of the initial response to the Australian outbreak, but, as a contingency measure, arrangements were made to source and register EI vaccine for possible emergency use. A number of potential EI vaccines were available including inactivated virus vaccines, live attenuated virus vaccines and virus-based vector (recombinant) vaccines (Paillot et al., 2006a,b). No available commercial vaccines contained the strain of virus identified in the Australian outbreak. However, from overseas experience, several vaccines were considered likely to produce acceptable immunity to the outbreak strain. A canary pox recombinant vectored vaccine (ProteqFlu, Merial) was chosen based on the following criteria:

1. Evidence that the vaccine would produce quicker and stronger immunity than inactivated vaccines and would reduce virus shedding within 14 days of the initial dose (Edlund Toulemonde et al., 2005).
2. Successful experience with the vaccine during the 2003 equine influenza outbreak in South Africa (Guthrie, 2006).
3. Ability to use laboratory techniques to enable 'differentiation of infected from vaccinated animals' (DIVA). Given that Australia's focus was on eradication, DIVA was considered crucial to be able to subsequently provide adequate evidence of freedom from infection.

Although not necessarily preventing infection, recombinant vaccines have been shown to be highly effective in protecting against clinical signs and greatly reducing virus excretion when compared to unvaccinated controls (Palliot et al., 2006b; Edlund Toulemonde et al., 2005; Minke et al., 2007).

Following advice from CCEAD, vaccination under an emergency use permit was approved and commenced in NSW on 28 September and Qld on 29 September, 5 weeks into the control program. In the early stages there was high demand for, but limited supply of vaccine, and different approaches and priorities were applied in different areas, and between NSW and Qld. In particular, the needs for vaccination for disease containment buffer zones had to be balanced against vaccination to protect high value horses considered to be at risk, both within the infected and in other jurisdictions, as the NMG had clearly identified that the containment and eradication of the disease and mitigation of socio-economic impacts were to be pursued in parallel.

There are varying opinions on the effectiveness of vaccination in the eradication of EI in Australia in 2007. Although, vaccination was undoubtedly an important factor that allowed movements of some horses to occur and events important to the horse racing and breeding industry to recommence, its effectiveness in containing and eliminating the disease is less clear (EI Epidemiology Support Group, 2009; Cowled et al., 2009). For disease managers, the role of vaccination is future response plans for EI is an important issue and the aim of this study was to test whether if vaccination had been used earlier, it would have made a useful contribution to reducing the subsequent spread of disease and size of the outbreak.

In this paper we describe the development of an EI model, based on an epidemiological analysis of the 2007 outbreak. This model was used to evaluate effectiveness of the mitigation strategies used and to test what effect vaccination may have had, if it had been used earlier in the response. We evaluate several different vaccination strategies.

2. Description of the epidemiological model

A stochastic state-transition simulation model for EI was developed to represent the Australian EI outbreak in space and time using a *susceptible-latent-infectious-recovered* (SLIR) approach. To implement vaccination, a new infection 'state' *vaccine immune* was added to the SLIR framework. The model uses a premises as the unit of interest, has a daily time step and is spatially-explicit (i.e. uses real premises locations based on coordinates). The model is written in MapBasic (Pitney Bowes MapInfo) and operates within a GIS framework (MapInfo Professional Version 9.5, Pitney Bowes MapInfo). It is adapted from a previously described simulation model of foot and mouth disease (Garner and Beckett, 2005; Beckett and Garner, 2007). To allow for the spatial heterogeneity in infection patterns observed in the outbreak, the affected area was divided into 16 regions (see below). EI transmission is simulated using a susceptible to latent transition probability based on regional risk rates.

The probability of infection was estimated using a similar approach to that described by Taylor et al. (2004) for analysing local spread of foot and mouth disease. In summary, for each of 16 regions, for each day of the study period, we counted the number of infectious premises, the number of at-risk premises and the number of new infections (based on estimated infection date) stratified by distance from all infectious premises. From this data the