A model of foot-and-mouth disease transmission and detection within a U.S. beef feedlot

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Introduction

Mathematical modeling is a tool to project the impact of a potential epidemic of foot-and-mouth disease (FMD) in disease-free countries. Most published models of FMD spread in the U.S. focus on farm to farm transmission and represent the farm as a homogenous unit. We developed a model of FMD transmission dynamics and clinical manifestation within a U.S. beef feedlot, incorporating typical feedlot layout, production management, and animal demographics. We used the model to assess the time to detection on the feedlot based on varying clinical FMD prevalence detection thresholds. We also estimated the impact of stopping movement of cattle to hospital pens following detection on the within-feedlot FMD outbreak.

Materials and Methods

We developed a stochastic SLIR (susceptible-latent-infectious-recovered) model nested in a meta-population of home pens and hospital pens in a U.S. beef feedlot. Within and between pens, contact of cattle in the feedlot were modeled. Five routes of FMD transmission between home pens were modeled: direct contact of cattle in the hospital pen, fence-line direct contact, via contamination of water troughs shared between home pens, via environment (dirt/feces) transferred by pen-riders between home pens, and airborne transmission. Morbidity rates for endemic diseases were used to model the probability that cattle are moved to the hospital pens. The model was parameterized based on literature review and an FMD expert survey. We modeled a feedlot of 24,000 cattle distributed in 120 pens with 200 head per pen, and 2 hospital pens. Ten FMD-latent cattle were introduced in the index pen near the center of the feedlot. Three surveillance detection thresholds were modeled: 3%, 5%, and 7% prevalence of clinical FMD cattle in the index pen. Two post-detection response scenarios were modeled: Scenario 1 continued cattle movements to the hospital pen following FMD detection; Scenario 2 stopped hospital movements on the day of detection.

Results

At 3% prevalence of clinical FMD in the index pen, detection occurred at a median of day 8 following FMD introduction in the feedlot and a median of 6 additional pens were infected. For the 5% threshold, detection occurred at a median of day 9 with a median 7 additional pens infected. For the 7% threshold, detection occurred at a median of day 10 with a median 8 additional pens infected. For the post-detection response Scenario 1, simulations showed that the within-feedlot outbreak took a median 96 days to fade-out and all pens were infected by a median of 47 days post FMD introduction. For Scenario 2, the time to fade out was similar across clinical prevalence detection thresholds (median 111-115 days) and all pens were infected by a similar days post FMD introduction (median 63-66 days).

Significance

We modeled a range of clinical FMD detection thresholds based on active observational surveillance by feedlot employees to estimate the impact on time to detection and FMD transmission in the feedlot. The day of detection and number of already infected pens in the feedlot increased as the percentage of clinical cattle in the index pen at detection increased from 3% to 7%, but this did not change the speed or duration of the within-feedlot outbreak if cattle movements to/from hospital pens were stopped upon detection. Delayed detection may increase time for FMD transmission off the feedlot before enhanced biosecurity is implemented. Stopping hospital-pen mixing of cattle slowed FMD transmission across the feedlot, but did not prevent eventual infection of all home pens. Stopping movements to the hospital pens would be a logistical and animal welfare challenge for the feedlot. Slowing the within feedlot outbreak, however, may allow time for vaccination to limit the final number of infected pens and animals, and may allow better control of labor demands in the outbreak. Further assessment of the impacts of vaccination and other control strategies in an infected feedlot is needed.