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Associations between feedlot management practices and bovine respiratory disease in Australian feedlot cattle

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ABSTRACT

Bovine respiratory disease (BRD) is the major cause of clinical disease and death in feedlot cattle. A prospective longitudinal study was conducted in a population of Australian feedlot cattle to assess associations between factors related to feedlot management and risk of BRD. In total, 35,131 animals in 170 pens (cohorts) inducted into 14 feedlots were included in statistical analyses. Causal diagrams were used to inform model building to allow separate estimation of total and direct effects. Multilevel mixed effects logistic regression models were fitted within the Bayesian framework.

The placement of pen water troughs such that they could be accessed by animals in adjoining pens was associated with markedly increased risk of BRD (OR 4.3, 95% credible interval: 1.4–10.3). Adding animals to pens over multiple days was associated with increased risk of BRD across all animals in those pens compared to placing all animals in the pen on a single day (total effect: OR 1.9, 95% credible interval: 1.2–2.8). The much attenuated direct effect indicated that this was primarily mediated via factors on indirect pathways so it may be possible to ameliorate the adverse effects of adding animals to pens over multiple days by altering exposure to these intervening factors (e.g. mixing history). In pens in which animals were added to the pen over multiple days, animals added $\geq$7 days (OR: 0.7, credible interval: 0.5–0.9) or 1–6 days (OR: 0.8, credible interval: 0.7–1.0) before the last animal was added were at modestly reduced risk of BRD compared to the animals that were added to the pen on the latest day. Further research is required to disentangle effects of cohort formation patterns at animal-level and higher levels on animal-level risk of BRD. Vaccination against *Bovine herpesvirus 1* at feedlot entry was investigated but results were inconclusive and further research is required to evaluate vaccine efficacy.

We conclude that there are practical interventions available to feedlot managers to reduce the risk of cattle developing BRD at the feedlot. We recommend placement of water troughs in feedlot pens so that they cannot be accessed by animals in adjoining pens. Further research is required to identify practical and cost-effective management strategies that allow longer adaption times for cattle identified prior to induction as being at higher risk of developing BRD.

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1. Introduction

Bovine respiratory disease (BRD) is the major cause of clinical disease and death in feedlot cattle (Edwards, 2010). Control and management of BRD are complicated because it is a multifactorial disease complex and different combinations of factors may result in clinical disease. While combinations of pathogenic organisms, environmental stressors and immunologically susceptible animals are necessary, no single organism is necessary for BRD to occur. Pathogens commonly implicated as contributing to development of BRD are ubiquitous in cattle populations. Transmission occurs by direct contact, aerosol and exposure to contaminated fomites in the animal's environment (Ellis, 2009). Any factor which influences the likelihood of susceptible animals in a feedlot being exposed to respiratory pathogens may therefore influence the risk of BRD. Shared water troughs were suggested as a possible mechanism whereby virus from animals persistently infected with bovine viral

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diarrhoea virus 1 (BVDV-1) and BVDV-2 may be transmitted to animals in adjoining pens (Loneragan et al., 2005). Shared pen water may also promote the spread of other respiratory pathogens, but this hypothesis has not been tested. Risk of pathogen transmission between pens may also depend on the numbers of cattle at the feedlot. However, while the incidence of BRD in North American feedlots peaks when the total number of cattle in feedlots peaks, during the autumn (fall) (Ribble et al., 1995a), this association is confounded by the influx of young light-weight cattle in autumn and increased commingling of newly introduced cattle with other cattle after feedlot entry in autumn relative to other seasons.

An understanding of which interventions and management strategies are most likely to be effective in mitigating the effects of BRD in feedlot cattle requires consideration of biological pathways linking putative risk factors with BRD. Many factors have been associated with risk of BRD in intensively-managed cattle populations (Taylor et al., 2010). Of these, exposures occurring when cattle are placed together in a feedlot pen to form a cohort and when these cattle are being fed feedlot rations (i.e. when they are 'on feed') at the feedlot are of particular interest because they are under the control of the feedlot manager, and hence may be more amenable to intervention than other risk factors.

Under typical Australian feedlot management, at induction, animals are identified and characteristics such as weight and breed are recorded prior to placement on feed in a feedlot pen. In an attempt to ameliorate the impact of BRD, some interventions are administered at this time. Multivitamin injections, typically vitamins A, D and E, are widely used in Australia despite inconsistent evidence that this reduces BRD incidence (Duff and Galyean, 2007; Cusack et al., 2009). In Australia, Rhinogard™, a modified-live vaccine registered to aid in the control of *Bovine herpesvirus 1* (BoHV-1) infection, is also commonly administered at induction. After induction, cattle from one or multiple sources are placed in feedlot pens. Pens are managed on a variation of the all-in, all out method. As with that method, once a pen is filled, typically after 60–150 days of feeding, all cattle are removed from the pen for slaughter before new cattle are placed in the pen. However, unlike that method, pens may be progressively filled over 1–14 days and progressively emptied over multiple days.

We refer to each population of cattle placed in a particular pen as a cohort. Management decisions relating to cohort formation include decisions about how many cattle to place in the same pen, how many source groups of cattle to commingle in that pen, and the time taken to fill the pen. The time taken to fill the pen increases variability in the amount of time available to each animal to adapt to final feedlot rations and final pen stocking density (the final number of animals per unit area in the pen). Reported associations between the number of animals in a cohort and risk of BRD have been inconsistent (Sanderson et al., 2008; Cernicchiaro et al., 2012a,b), but these researchers were not able to adjust for the amount of commingling with other cattle prior to feedlot entry.

Most prior research investigating the effects of rations has been conducted at the pen or cohort level. Associations between ration characteristics and BRD incidence have not been observed consistently (Duff and Galyean, 2007; Cusack et al., 2009). However, marked variation in individual animal feeding behaviour, rumenal pH and microbial ecology responses to the introduction of highly fermentable diets have been observed (Schwartzkopf-Genswein and McAllister, 2005). Accordingly, a possible link between animal-level differences in the response to the introduction of rations and subsequent associations with BRD risk may go undetected in cohort-level studies. There is a lack of studies examining associations between rations changes over time and BRD risk at the animal level.

The National Bovine Respiratory Disease Initiative was a nationwide prospective longitudinal study designed to investigate putative risk factors for BRD in Australian feedlot cattle (Hay et al., 2014). In the current study, one of a number of studies conducted as part of the Initiative, we evaluated associations between practices under the control of feedlot managers (feedlot management factors i.e. exposures occurring during the formation of cohorts and during the animals' time on feed in feedlot pens) and risk of BRD.

2. Materials and methods

Detailed descriptions of the study design, study population and analysis methods have been presented elsewhere (Hay et al., 2014). Commercial feedlots were selected, and cattle sourced from throughout the cattle-producing regions in Australia were enrolled at induction and assembled into cohorts during the usual management processes at the feedlots. Each animal's induction date was defined as its 'day 0', and time at risk of acquiring BRD was measured from this point for each animal. The induction period for a cohort was the time from the first to last animal's induction date. Each cohort consisted of one of more 'group-13s' where a group-13 was determined from the identification of the source farm for each animal 13 days before induction (i.e. day -13) and consisted of all animals at the same farm on that day that later joined the same cohort (Hay et al., 2014). A total of 35,160 animals were inducted into study cohorts from March 2009 to December 2011, of which 35,131 animals had sufficient data for inclusion in the current study. The nested hierarchical study population comprised animals clustered within 1077 group-13s clustered within 170 cohorts clustered within 14 feedlots.

The unit of analysis was the individual animal. Each animal was monitored for BRD from its induction date until it was removed from the study cohort for any reason. The outcome of interest was the development of BRD during the first 50 days following induction. The case definition was based on clinical signs consistent with a diagnosis of respiratory disease (i.e. 'pneumonia', 'respiratory', 'BRD' or 'infectious bovine rhinotracheitis') as recorded by feedlot staff in computerised hospital records in the usual course of feedlot management (Hay et al., 2014).

Risk factors of interest in the current study consisted of exposures during the formation of cohorts and during the animals' time on feed in feedlot pens. Biologically plausible mechanisms through which risk factors were postulated to increase risk of BRD consisted of exposure to respiratory pathogens, reduction in animal or herd-level immunity to specific pathogens, and general impairment of immunological or neuroendocrine function via exposure to stressors. For example, cohort formation involved exposure to a large number of animals, commingling groups of animals from multiple sources over differing periods of time, disruption to the animals' social hierarchies, and the demands of adaptation to feedlot pen conditions with the inherent changes in animal density, introduction of novel rations, and use of feed bunks and water troughs, resulting in exposure to multiple stressors and BRD pathogens.

Exposure variables relating to cohort formation aimed to describe the number of animals and the amount of commingling that study animals were exposed to, the time period over which animals were added to the cohort, and animal-level adaptation time. The cohort fill pattern, ('Cohort fill': 1 day, >1 day), was a cohort-level variable that described the duration of the cohort's induction period. Some animals from six feedlots had additional time to adapt to ration changes and other feedlot management practices before study monitoring for BRD occurrences commenced from their induction date, because they were put on feed in a feedlot pen prior to induction. The number of days between the animal's first day on feed (DOF1) and its day 0 (the animal's induction date) was described using a three-category, animal-level variable, 'DOF1 to day 0' (0 days, 1 or 2 days, $\geq$3 days). The latest animal-level

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