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Original Article

The relationship between failure of passive transfer and mortality, farmer-recorded animal health events and body weights of calves from birth until 12 months of age on pasture-based, seasonal calving dairy farms in New Zealand

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ABSTRACT

The effects of failure of transfer of passive immunity (failure of passive transfer, FPT), defined by serum total protein (STP) $\leq$ 52 g/L at 1–7 days of age, on mortality, morbidity and body weight were investigated from birth until weaning in 3829 calves on 106 pasture-based, seasonal calving dairy farms in nine regions of New Zealand. A subset of 2053 calves from 35 farms in two regions from the main cohort of calves and farms were enrolled to monitor the longer term effects of FPT until 12 months of age. Calves with FPT had a greater odds of farmer-recorded animal health events (odds ratio, OR, 1.68; 95% confidence interval, CI, 1.29–2.19) prior to weaning, and a greater odds of mortality by 6 (OR 2.19; 95% CI 1.04–4.62) and 12 months of age (OR 2.21; 95% CI 1.22–4.00). FPT was associated with a lower ($P < 0.05$) body weight at weaning, and at 6, 9 and 12 months of age, but these differences were small, ranging from 0.93 kg at weaning to 3.30 kg at 12 months of age. For every 10 g/L increase in STP concentration, the odds of mortality was 13% lower at weaning (OR 0.87; 95% CI 0.59–1.28) and 37% lower at each of 6 months of age (OR 0.63; 95% CI 0.44–0.90), 9 months of age (OR 0.63; 95% CI 0.4–0.88) and 12 months of age (OR 0.63; 95% CI 0.60–0.66). In conclusion, FPT and decreased STP concentration were associated with increased morbidity and mortality, and slightly reduced growth rates, in calves managed under a pasture-based, seasonal calving system in New Zealand.

Introduction

Newborn calves are immunologically naïve, because immunoglobulins (Igs) cannot be transferred from the dam to the foetus via the placenta (Borghesi et al., 2014). The neonatal calf is dependent on Ig from colostrum to provide passive immunity until its immune system becomes active. Serum immunoglobulin G (IgG) concentrations can indicate the degree of protection provided by colostrum. IgG concentrations $<$ 10 g/L indicate a failure of transfer of passive immunity (failure of passive transfer, FPT) (Besser et al., 1985). Alternatively, serum total protein (STP) concentrations provide a reasonable estimate of IgG and are useful for investigating FPT at herd level if healthy calves $<$ 1 week of age are tested more than 6 h after they have ingested colostrum (McGuirk and Collins, 2004). Using IgG or STP, the prevalence of FPT has been reported as 19–40% in dairy herds in North America, Australia and New Zealand (Beam et al., 2009; Vogels et al., 2013; Cuttance et al., 2017), indicating that many calves do not receive adequate immune protection following birth.

FPT has been associated with increased morbidity, mortality and lower growth rates of calves. Virtala et al. (1999) and Pardon et al. (2015) reported an increased likelihood of developing respiratory disease with lower serum IgG concentrations, while Donovan et al. (1998) reported that the prevalence of septicaemia $<$ 45 days of age decreased as STP concentration (at 2–8 days of age) increased linearly from 40 to 80 g/L. They also reported that mortality risk from 0 to 6 months of age decreased when STP concentration increased from 40 to 60 g/L, but not thereafter. Similarly, Tyler et al. (1998) observed that mortality risk in calves $<$ 16 weeks of age was incrementally lower for each 5 g/L increase in STP concentration up to 60–64 g/L. Calves with STP concentrations $<$ 40 g/L had a 4.6 times greater risk of mortality than calves with an STP concentration of

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60 g/L. The relationship between FPT and growth rates is less clear; reduced growth rates at different rearing stages have been reported in calves with lower IgG concentrations (Furman-Fratczak et al., 2011; Pardon et al., 2015). Overall, the evidence indicates that calves with better immune protection from ingested colostrum are less likely to develop diseases, and more likely to survive and grow at higher rates.

Most research on FPT has been conducted in the northern hemisphere in housed systems. To the authors' knowledge, no studies have assessed the relationships between FPT and mortality, morbidity and growth rates in the pasture-based, seasonal calving systems predominant in New Zealand and many parts of Australia. In these systems, calves are born outdoors and then group reared indoors with increasing access to grazed pasture from ~1 month of age. Following weaning (~12 weeks of age), animals are managed separately from the milking herd, often on a different farm, and graze pasture as their base diet. These differences in management between calves in New Zealand and those in the northern hemisphere could result in different relationships between FPT and mortality, disease and growth rates.

In the northern hemisphere, the most common consequence of FPT is an increased risk of respiratory disease (McGuirk, 2008; Windeyer et al., 2014) which is one of the most common diseases affecting the health of dairy calves in such systems (Virtala et al., 1996; Lago et al., 2006). However, respiratory disease is uncommon in calves New Zealand (Fairley, 1996; Arlidge, 1999), and, therefore, FPT is unlikely to substantially alter the risk of respiratory disease, which could markedly affect its potential association with morbidity, mortality and growth rates.

The aims of the present study were to determine the effects of FPT on farmer-diagnosed animal health events, and mortality and growth of dairy calves from pasture-based, spring-calving herds across New Zealand at weaning, and at 6, 9 and 12 months of age.

Materials and methods

Experimental design

All procedures using cattle were approved by the AgResearch Ruakura Animal Ethics Committee, Hamilton, New Zealand (approval number 13590; date of approval 2 July 2015). The study was carried out on spring-calving pasture-based farms in nine regions across New Zealand (Northland, Waikato, Taranaki, Bay of Plenty, Manawatu, Canterbury, Otago, Southland and the West Coast of the South Island) from July 2015 to September 2016.

On each farm, blood samples were collected from calves from 24 h and 7 days of age, and tested for FPT (STP concentration < 52 g/L; Cuttance et al., 2017). On three occasions throughout the seasonal calving period (early, middle and late calving), 10 calves (of any sex) were sampled per farm, except in two regions (Waikato and Canterbury), where 20 replacement heifers were sampled at each visit; these heifers were monitored from birth until the end of their first lactation. Data recorded for each calf included breed, age, method/volume/timing of colostrum feeding and questions about their health on arrival at the rearing shed. The STP results were available to study personnel only until the study period had ended. Calves designated to be in the long term section of the study (Waikato and Canterbury) were tagged with a pink ear tag pre-numbered with a designated trial number.

Animal health events and mortality records

Forms were provided to all enrolled farmers to record animal health events and mortality. Guidelines and descriptions on the commonly expected diseases were provided. The forms were collected at each farm visit, with the final form collected at the final weaning date of the last group of calves. In the long term part of the study, farmers took on the responsibility for continued recording and were contacted monthly by technicians overseeing the study to ensure conformity with its requirements.

Weight measurements

All sampled calves that were not sold or sent to slaughter were weighed on electronic scales at weaning (±7 days) by a technician. Calves enrolled in the long term part of the study were also weighed at 6, 9 and 12 months of age.

Statistical analysis

Key outcomes

The key outcomes from arrival at the rearing shed until weaning were weaning body weights, farmer-recorded mortality risk and farmer-recorded animal health event risk. Key outcomes for calves in the long term part of the study were weaning body weights and mortality risk from the time they were sampled (1–7 days of age) to weaning, and 6, 9 and 12 months of age, as well as from weaning to 12 months of age.

Optimal serum total protein concentration cut-off to determine failure of passive transfer status

Data from body weights at 12 months of age were used to determine the STP concentration cut-off at which FPT was declared. A linear mixed model, with farm and farmer as crossed random effects, and region, age at weaning, breed and sampling period as the remaining fixed effects, were run in separate models for all whole number STP concentration cut-offs from 48 to 60 g/L; the model with the smallest Akaike information criterion (AIC) was considered to be the best fit for the data and the associated STP cut-off value was used in all models to define FPT. The same process, using a generalised linear mixed model, was used to determine the STP concentration cut-off for FPT status for 12 month mortality risk.

Mortality risk and recorded animal health event risk

A generalised linear mixed model, with farm as a random effect, was used to assess the relationship between mortality risk at each time period, and FPT and STP concentration. A full multivariable model, including all possible risk factors, was produced using criteria suggested by Zuur et al. (2009). Potential risk factors included age of calf at the time of blood sampling, region, breed of calf, sampling period (early, middle or late calving period visit), farmer-reported issues with each calf upon entry to the rearing shed, technician-reported calf problems at the time of sampling, age and breed of dam, method of colostrum administration and number of colostrum feeds. Separate models were run with the presence or absence of FPT or STP as the predictors of interest. Dam age was included as a categorical variable; dams > 10 years of age were collapsed into the category ≥ 10 years of age. Biologically plausible interaction terms (e.g. age in days at blood sampling and FPT status) were also included in this model. Fixed variables were removed using backward elimination if the log likelihood ratio test between nested models had $P > 0.05$, until all remaining fixed effects were $P \leq 0.05$. Linearity of the continuous variables STP and age at sampling were assessed by plotting these values against the log odds of mortality from the model. If they were non-linear, they were either categorised or centred on their mean, and appropriate polynomial functions added. A variable was considered to be a confounder if coefficients or standard errors (SEs) of remaining fixed effects changed by $\geq 20\%$; these were retained in the model even if not significant, as was FPT status and STP concentration. Model diagnostics were evaluated to assess model fit and for outliers or influential observations. Only animal health events prior to weaning were analysed, since animal health event data were not collected adequately by all farmers after weaning. A generalised linear mixed model, with farm as a random effect, was used, with the same potential risk factors as included for mortality risk.

Body weights

Linear mixed effects models were run for all body weights at weaning, and at 6, 9 and 12 months of age; linear STP concentration and binary FPT status were modelled separately. Farm was included as a random effect for weaning and 6 month weights; farm and farmer were included as crossed random effect intercepts for 9 and 12 month weights. Potential risk factors analysed were as for mortality risk, plus age at weighing in days. Linearity of the continuous variables STP concentration and age were assessed using scatterplots against residuals. If they were non-linear, polynomial functions were added. Variable selection and model diagnostics were the same as described for mortality risk. All statistical analyses were carried out using R (Version 3.3.3, R Foundation for Statistical Computing).[1]

Results

Consort diagrams of the number of herds and calves included in the analyses are presented in Figs. 1 and 2.

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[1] See: https://www.r-project.org/https://www.r-project.org/ (accessed 19 December 2017).