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ORIGINAL RESEARCH

Effect of neonatal immunoglobulin status on the outcomes of spring-born suckler calves

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Abstract

Background: Successfully rearing beef calves to weaning and beyond determines the economic performance of a beef farm. As such, it is important to understand the factors influencing performance outcomes.

Methods: This study recorded the health events, mortality and growth rates of 674 calves born on 50 commercial beef farms in Great Britain using a postsampling questionnaire. All calves had a known postcolostral serum IgG status.

Results: Preweaning mortality in the study population was 1.5% (10/674 calves), while the treatment rate was 6.4% (43/674 calves). Serum IgG, calf sex and dystocia were significant predictors of whether a calf died and/or required treatment. Average daily liveweight gain was calculated for calves where weaning weights were provided ($n = 513$). Serum IgG and calf sex were consistent predictors of calf growth rates, while birthweight and whether the calf was born to a cow or heifer were predictive in a model where average daily liveweight gain was converted to a binary response variable using the mean average daily liveweight gain on the calf's farm of origin.

Limitations: Morbidity and mortality were lower than comparable studies, potentially due to limitations in the study design.

Conclusion: Serum IgG and calf sex were significant explanatory variables that affected beef calf average daily liveweight gain. For every 5 g/L increase in serum IgG, the odds ratio of dying and/or requiring treatment decreased by 0.86.

INTRODUCTION

Calves are born agammaglobulinemic, and rely on the ingestion and uptake of colostral immunoglobulins from the dam after birth. There is a known, tight time-frame in the first 24 hours following birth in which a calf is able to absorb these large immunological molecules, after which the protection offered is purely local to the gastrointestinal tract epithelium.[1] Failure of this transfer of antibodies from colostrum to the calf's bloodstream is known as failure of passive transfer (FPT).[1] A recent consensus paper on FPT in dairy calves has proposed four categories for the assessment of serum IgG concentration (s[IgG]), with less than 10 g/L being classified as 'poor' (also termed 'complete FPT'), and over 25 g/L being classified as 'excellent'.[2] s[IgG] values between 10 and 25 g/L are often termed 'partial FPT'.

Practical interest in FPT stems from research into the impact of FPT on the calf's future health and performance. Previous studies have assessed the outcomes in suckled beef calves in Canada and the United States that suffered from poor passive transfer of immunoglobulins. One study of 601 calves from 152 commercial beef herds in Canada described the lowered odds of treatment or death as s[IgG] increases.[3] Likewise, a study conducted on a single research station in the USA described how a lower s[IgG] was significantly associated with higher morbidity and mortality rates, and lower average daily liveweight gain (ADLWG).[4] Both these studies suggested an s[IgG] threshold of 24 g/L, below which there are increased odds of treatment (odds ratio [OR] 1.5–1.6) and death (OR 1.5–2.7) in preweaned suckler calves.[1,2] An older study of 263 beef calves in the United States used a much lower threshold of 8 g/L, which consequently identified a bigger impact on preweaning mortality (OR 5.4) and morbidity (OR 3.2) for calves with extremely low s[IgG].[5] The impact of FPT on ADLWG is less clear. Dewell et al.[2] assessed 1568 crossbred beef calves on a single farm in Nebraska over a 3-year period, and is the only study to date to conclude that calves with s[IgG] greater than 27 g/L weighed 3.35 kg more at 205 days than calves with lower s[IgG]. The only study conducted in Great Britain (GB) followed 381 purchased calves as they entered a single commercial calf-rearing unit, and it concluded that there was no significant relationship between s[IgG] and daily liveweight gain (DLWG) or disease incidence.[6] No studies have identified a relationship between FPT and postweaning ADLWG.[4,6]

In dairy calves, serum total protein (sTP) is often used as a proxy for s[IgG] due to its ease of analysis.[2] Various studies in dairy calves, using sTP thresholds of 6.5 and 5.7 g/L, have shown an increased risk for septicaemia and pneumonia in early life for calves that suffered from FPT.[7,8] However, these studies did not show an increased risk for neonatal diarrhoea. Using the s[IgG] 10 g/L threshold, various studies have shown an increased risk for disease incidence in calves with an s[IgG] of less than 10 g/L,[2,9,10] with ADLWG also lower in calves with FPT.[7] As a result of these consequences, FPT is considered to represent a significant economic cost to both dairy and beef producers. One meta-analysis looking into the economic impacts of FPT concluded that the cost of FPT per calf averages €60 (€10–109) and €80 (€20–139) for dairy and beef calves, respectively,[11] rising to €95 and €132, respectively, in herds with high prevalence of FPT.

As described previously, most of the studies into the outcomes of FPT in calves have been performed in North America and focused on dairy calves, rather than beef suckler calves. Therefore, there is a current lack of evidence published for suckler calf outcomes under a range of commercial management systems in the United Kingdom.

The objective of this study was to assess the outcome of calves in relation to both morbidity and mortality following s[IgG] assessment, as well as the calf and dam factors around birth that may influence calf outcome, across 50 commercial spring-calving suckler farms in the United Kingdom. This study also examined the growth rate of calves during the preweaning period, in order to assess the relationship between ADLWG and passive transfer status.

MATERIALS AND METHODS

As part of a separate project to assess FPT in beef calves,[12] a convenience sample of 84 spring-calving beef farms from throughout GB were enrolled in the winter of 2017/2018 through their veterinary practices (74 farms) or the Agriculture and Horticulture Development Board (AHDB) strategic farm programme (10 farms). Farms were eligible if herd size and calving pattern meant that 15 calves at 2–5 days old could be blood sampled by their veterinary surgeon at two visits in spring 2018 for the quantification of s[IgG] using radial immunodiffusion on serum samples. Standardised sampling kits including weigh tapes and data collection forms were sent to the farm's own veterinary surgeon, who was responsible for collecting the samples and farm data. In total, blood samples were obtained from 1131 calves from 84 farms.[12]

Outcome data on the sampled calves were collected via a voluntary follow-up questionnaire after participation in the original project. Farmers were sent a list of previously enrolled calves' identification numbers, and asked a series of questions about the calves' outcomes. They were asked if each calf was alive as of 1 December 2018 (approximately 9 months after birth: yes/no), date of death, cause of death if known, dates of any treatments the calf required, reasons for treatments and weight at weaning/sale, along with a date for the weaning/sale weight. The method of weighing at weaning/sale was not detailed, but was presumed to be weighscales in most cases. Using this and the weights recorded by the veterinary surgeon at blood sampling, the ADLWG was calculated for each calf. Not all responses contained full datasets for each calf; therefore, total numbers of calves available to analyse varies.

Statistical analyses were undertaken using R statistical programme v4.2.0[13] and packages 'ggplot2', 'tidyverse' and 'lme4'. Thirteen explanatory variables were used to build univariable models for three different measures of growth rate performance. ADLWG was initially analysed as a continuous variable. Subsequently, ADLWG was converted into a binary variable using the study mean ADLWG (yes/no, >/<1.1 kg/head/day) as a threshold for 'equal to or above average' and 'below average' growth rates (referred to as 'study growth rate'). Finally, a second binary variable was also generated by comparing the calf's ADLWG to the mean ADLWG on its farm of origin (yes/no, referred to as 'farm growth rate'). The explanatory variables included were s[IgG] (continuous), s[IgG] <10 g/L (yes/no), s[IgG] <24 g/L (yes/no), calf sex (male/female), calf birthweight (continuous), dam condition at the time of sampling (ideal 2.5–3.5/5, thin <2.5/5, fat >3.5/5), dam condition score (five-point scale, 0.25 graduation scale), dam parity (heifer or cow), calving assistance required (yes/no), feeding assistance (four grades: 0: no assistance; 1: lead to dam; 2: bottle/tube fed dam's own colostrum; 3: bottle/tube fed artificial colostrum), calf breed (five levels: Aberdeen Angus, Charolais, Limousin, Simmental and 'Other'), calf breed (native/continental) and twins (yes/no). Full details of the explanatory variables can be found in Bragg et al.[12] The significant variables from the univariable analysis were taken forward into the building of generalised linear mixed models (GLMM) and linear mixed models (LMM), using a p-value of less than 0.1 for significance.

Univariable models were built for 12 explanatory variables for the binary calf outcome of dead and/or treated versus alive and no treatment. These included s[IgG] (continuous, binary <10 g/L and binary <24 g/L), calf sex, dam condition (categorical and scaled), dam parity, calving assistance level, feeding assistance level, calf breed (breed groups and native/continental) and twins (yes/no). Significance for inclusion in GLMM model building was taken as $p < 0.1$. Stepwise removal of variables was performed on all GLMMs using the significance of an explanatory variable to determine removal order and the effect on the AIC (Akaike Information Criterion) of the model to determine the effect that removal had. In all mixed models, the random effects structure was calf nested within farm. For all LMMs, residuals were inspected during model validation, while all GLMMs using a binomial distribution were assessed for overdispersion.

RESULTS

Descriptive results

From the original 84 farms, a questionnaire response rate of 60% (50/84) was obtained, providing information on 674 out of the original 1131 calves. Out of the 674 calves, 10 calves were reported dead, 20 had been sold and 643 were still alive as of 1 December 2018, with one unknown status. Forty-three calves were reported to have required some form of treatment, compared to 629 calves having no treatment in the period of birth to 1 December 2018, with two unknown statuses. Reasons for treatment included diarrhoea (n = 8), joint ill (n = 6), lameness (n = 10), navel ill (n = 7), pneumonia (n = 10) and other (n = 2). For analysis of calf outcomes, calves were categorised into a binary response variable of 'Alive and no treatment recorded' (n = 624) or 'Dead and/or required treatment' (n = 51), with three calves that received a treatment going on to die. The 51 calves that died and/or required treatment were from 20 different farms. The crude risk of mortality and/or treatment for calves with an s[IgG] less than 10 g/L was 15.8% (12/76), compared to 6.6% (38/580) for calves with an s[IgG] above this value. When using a cut-off of 24 g/L s[IgG], the crude risk was 13.1% (27/206) for calves below this threshold and 5.1% (23/450) for calves above it.

Birthweights, weaning weight and date of weighing (or known weight as of 1 December 2018) were provided for 521 calves from 42 farms, and ranged from 147 to 495 kg (mean 303.8 kg), with ADLWG ranging from 0.22 to 1.79 kg/day (mean 1.17 kg/day). Age at weighing ranged from 129 to 314 days.

Average daily liveweight gain analysis

Initial analysis considered ADLWG as a continuous variable with normal distribution. Using the 'study growth rate' threshold of 1.1 kg/day, 346 calves fell into the 'equal to or above average' category and 175 into the 'below average' growth rate category. Farm mean ADLWG ranged from 0.79 to 1.36 kg/day, with a mean of 1.17 kg/day. Using the 'farm growth rate' threshold, 252 calves had an ADLWG below the mean ADLWG of their farm, and 269 calves equalled or achieved over the mean ADLWG for their farm.

Preliminary analyses indicated that the relationship between continuous ADLWG and s[IgG] had a poor correlation (Figure S1). s[IgG] was therefore converted into a binary explanatory variable using the previously described thresholds of 10 and 24 g/L. Neither the 10 or 24 g/L s[IgG] thresholds was a significant predictor of ADLWG (p = 0.56 and 0.73, respectively) in the univariable model. ADLWG as a continuous variable was also modelled against 10 other explanatory variables, and as two different binary variables, as described above, summarised in Table 1 and illustrated in Figure 1. ADLWG as a continuous variable had seven significant explanatory variables to take forward for multivariable modelling, with the six categorical variables presented in Figure 1. Study growth rate had six significant explanatory variables, and farm growth rate had three significant explanatory variables. s[IgG] was not significant in any of the univariable analyses, but as previous studies have identified a relationship between s[IgG] and ADLWG, s[IgG] was included in the initial model building for all three multivariable models.

The final GLMM outputs following model selection for study growth rate and farm growth rate are presented in Table 2, and the LMM output for ADLWG as a continuous variable is presented in Table 3.

The results from the GLMM for study growth rate showed that calf birthweight, calf sex (being male) and s[IgG] were significant predictors of whether a calf grew above the study mean ADLWG of 1.1 kg/day. The GLMM results for farm growth rate showed similar results, with the addition of dam parity as a significant predictor. Therefore, when controlling for between farm differences in ADLWG, a calf being born to a heifer is more likely to have a growth rate below the farm's average, compared to calves born to a cow.

The LMM for ADLWG retained all seven variables following stepwise removal, that is, the AIC of the model significantly deteriorated following the removal of any explanatory variables. The results for this model were similar to the two logistic regression analyses, with calf sex (being male), dam parity (being born to a heifer) and s[IgG] being significant predictors of calf ADLWG (Table 3). Calf birthweight was not a significant explanatory variable in the LMM.

Calf outcome analysis

Univariable analysis of calf outcome as a binary response variable ('Alive and no treatment required' vs. 'Dead and/or required treatment') identified nine variables as significant, which were taken through to

TABLE 1 *p*-Values from the preliminary univariable analysis of variables influencing calf average daily liveweight gain (ADLWG)

	Calf ADLWG (kg/day)		
Explanatory variable	**ADLWG (continuous)**	**Study growth rate (binary 1.1 kg/day)**	**Farm growth rate (binary herd mean)**
s[IgG] (continuous)	0.405	0.327	0.119
s[IgG] <10 g/L (binary)	0.555	0.22	0.588
s[IgG] <24 g/L (binary)	0.733	0.59	0.102
Calf sex (male/female)	**<0.001**	**<0.001**	**<0.001**
Calf birthweight (continuous)	**<0.005**	**<0.005**	**<0.001**
Dam condition (fat/ideal/thin)	**0.006**	**0.014**	0.473
Dam BCS (score 1–5)	**<0.001**	**<0.001**	0.574
Dam parity (heifer/cow)	**<0.001**	**<0.005**	**0.015**
Calving assistance (yes/no)	0.807	0.99	0.95
Feeding assistance (4 levels)	**0.039**	0.19	0.934
Calf breed (5 levels)	**<0.001**	**0.027**	0.744
Calf breed (native/continental)	**<0.001**	0.135	0.769
Twins	0.156	**0.068**	0.457

Note: Significance: $p < 0.1$ was used as the threshold for multivariable model building, highlighted in bold. ADLWG was analysed as a continuous variable (linear regression) or as two different binary variables (logistic regression for continuous and chi-squared for categorical explanatory variables), generated using either the study mean ADLWG of 1.1 kg/day (study growth rate) or the farm mean ADLWG (farm growth rate).
Abbreviations: BCS, body condition score; s[IgG], serum IgG.

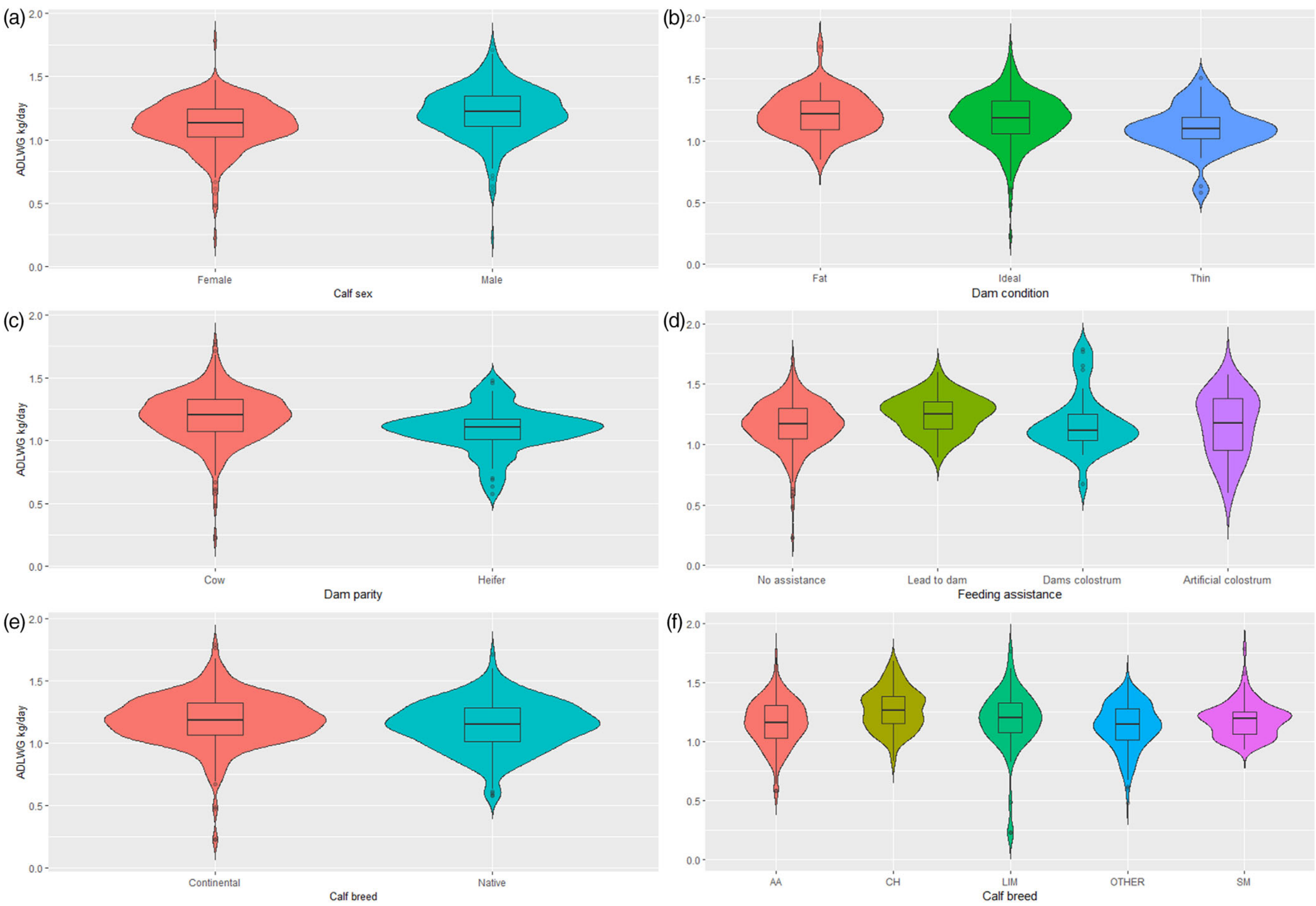

FIGURE 1 Violin and box/whisker plots for calf average daily liveweight gain (ADLWG) (kg/day) versus (a) calf sex (male/female), (b) dam body condition at calving (industry standards: fat >3.5/5, ideal 2.5–2.5/5 and thin <2.5/5), (c) dam parity (heifer or cow), (d) level of colostrum feeding assistance (no assistance, lead to dam, bottle/tube fed dam's colostrum, bottle/tube fed artificial colostrum), (e) breed categories (native or continental) and (f) calf breed (AA: Aberdeen Angus; CH: Charolais; LIM: Limousin; SM: Simmental; OTHER: all other breeds reported with <50 calves per category)

TABLE 2 Generalised linear mixed model (GLMM) results following stepwise model selection for study growth rate (A) and farm growth rate (B)

Variable	Level	Number (*n*)	*p*-Value	OR (95% CI)
A. Study growth rate (>1.1 kg/day)				
Serum IgG (g/L)	Continuous		**0.014**	**1.01(1.00–1.03)**
Calf sex	Female	301	Ref	Ref
	Male	350	**<0.001**	**3.45 (2.12–5.62)**
Calf birthweight	Continuous		**0.025**	**1.03 (1.00–1.06)**
Dam parity	Cow	541	Ref	Ref
	Heifer	98	0.122	0.59 (0.30–1.15)
B. Farm growth rate (above herd mean)				
Variable	**Level**	**Number (*n*)**	***p*-Value**	**OR (95% CI)**
Serum IgG (g/L)	Continuous		**0.022**	**1.01 (1.00–1.02)**
Calf sex	Female	301	Ref	Ref
	Male	350	**<0.001**	**2.93 (2.01–4.23)**
Calf birthweight	Continuous		**0.013**	**1.02 (1.00–1.03)**
Dam parity	Cow	541	Ref	Ref
	Heifer	98	**0.035**	**0.56 (0.33–0.96)**

Note: Farm ID is included as a random variable. Significance ($p < 0.05$) is indicated in bold.
Abbreviations: CI, confidence interval; OR, odds ratio.

TABLE 3 Linear mixed model (LMM) results following stepwise model selection for average daily liveweight gain as a continuous variable

Variable	Level	Number (*n*)	*p*-Value	Estimate	95% CI
Serum IgG (g/L)	Continuous		**0.029**	**0.001**	**0.000-0.002**
Calf sex	Female	301	Ref	Ref	Ref
	Male	349	**0.00**	**0.096**	**0.067–0.13**
Calf birthweight (kg)	Continuous		0.25	0.001	–0.000 to 0.002
Dam condition	Ideal (BCS 2.5–3.5/5)	514	Ref	Ref	Ref
	Thin (BCS <2.5)	60	0.197	–0.037	–0.094 to 0.019
	Fat (BCS >3.5)	68	0.897	–0.004	–0.062 to 0.055
Dam heifer/cow	Cow	541	Ref	Ref	Ref
	Heifer	98	**0.024**	**–0.054**	**–0.101** to **–0.007**
Feeding assistance	No assistance	520	Ref	Ref	Ref
	Lead to dam	55	0.194	0.038	–0.019 to 0.085
	Fed dams own colostrum (bottle/tubed)	34	0.506	0.021	–0.042 to 0.095
	Fed artificial colostrum (bottle/tubed)	33	0.740	–0.013	–0.088 to 0.663
Calf breed	AA	146	Ref	Ref	Ref
	CH	94	0.162	0.051	–0.207 to 0.124
	LIM	121	0.914	–0.004	–0.079 to 0.072
	SIM	94	0.728	0.012	–0.055 to 0.078
	Other	220	0.609	–0.016	–0.079 to 0.046

Note: Farm ID is included as a random variable. Significance ($p < 0.05$) is indicated in bold.
Abbreviations: AA, Aberdeen Angus; BCS, body condition score; CH, Charolais; CI, confidence interval; LIM, Limousin; SIM, Simmental.

multivariable analysis (Table 4). The clear difference in s[IgG] between calves that died and/or required treatment and those that did not is evident in Figure 2.

The final GLMM for calf outcome retained only three variables. These were s[IgG] as a continuous variable, calf sex and calving assistance (Table 5). This model demonstrated that calves with increasing s[IgG] levels are at reduced risk of death and/or requiring treatment, with every 5 g/L increase in s[IgG] resulting in an OR of calves dying and/or requiring treatment of 0.86. Male calves and calves that required assistance at calving were also at higher likelihood of having a morbidity or mortality event, with an OR of 2.78 for calves that required assistance and an OR of 3.74 for male calves. The confidence intervals for both of these variables are wide, which likely reflects the relatively

TABLE 4 Univariable analysis for calf outcome (Alive and no treatment vs. Dead and/or treatment)

Variable	Level	Total number	Number affected	Proportion (%)	*p*-Value
s[IgG]	Continuous				**<0.001**
s[IgG] <10 g/L	Yes	76	12	15.8	**<0.01**
	No	580	38	6.5	
s[IgG] <24 g/L	Yes	206	27	13.1	**<0.001**
	No	450	23	5.1	
Sex	Female	301	12	4.0	**0.001**
	Male	349	37	10.6	
Dam condition	Fat	68	3	4.4	**0.063**
	Ideal	514	38	7.4	
	Thin	60	9	15.0	
Dam BCS	2	40	7	17.5	0.111
	2.25	12	2	16.7	
	2.5	159	14	8.8	
	2.75	11	2	18.2	
	3	238	10	4.2	
	3.5	104	12	11.5	
	4	61	3	4.9	
Dam parity	Cow	541	34	6.3	**<0.001**
	Heifer	98	16	16.3	
Calving assistance	No	528	31	5.9	**<0.001**
	Yes	123	19	15.4	
Feeding assistance	No assistance	520	29	5.6	**<0.001**
	Lead to dam	55	5	9.1	
	Dam's colostrum	34	10	29.4	
	Artificial colostrum	33	3	9.1	
Breed	AA	146	13	8.9	0.255
	CH	94	9	9.6	
	LIM	121	11	9.1	
	Other	220	16	7.3	
	SIM	94	2	2.1	
Native	Continental	455	35	7.7	0.847
	Native	220	16	7.3	
Twins	No	641	47	7.3	**0.068**
	Yes	15	3	20.0	

Note: Significance of $p < 0.1$ (highlighted in bold) used to select variables taken forward for multivariable analysis. Logistic regression used for continuous variables (s[IgG]) and chi-squared analysis used for categorical variables.
Abbreviations: AA, Aberdeen Angus; BCS, body condition score; CH, Charolais; LIM, Limousin; SIM, Simmental; s[IgG], serum IgG.

TABLE 5 Generalised linear mixed model (GLMM) results for calf outcome analysis

Variable	Level	No. of calves (*n*)	*p*-Value	OR (95% CI)
s[IgG]	Continuous		**0.015**	**0.97 (0.95–0.99)**
Sex	Female	301	Ref	Ref
	Male	350	**0.001**	**3.74 (1.66–8.42)**
Calving assistance	No	529	Ref	Ref
	Yes	123	**0.015**	**2.78 (1.22–6.31)**

Note: Farm ID is included as a random variable. Significance ($p < 0.05$) is indicated in bold.
Abbreviations: CI, confidence interval; OR, odds ratio; s[IgG], serum IgG.

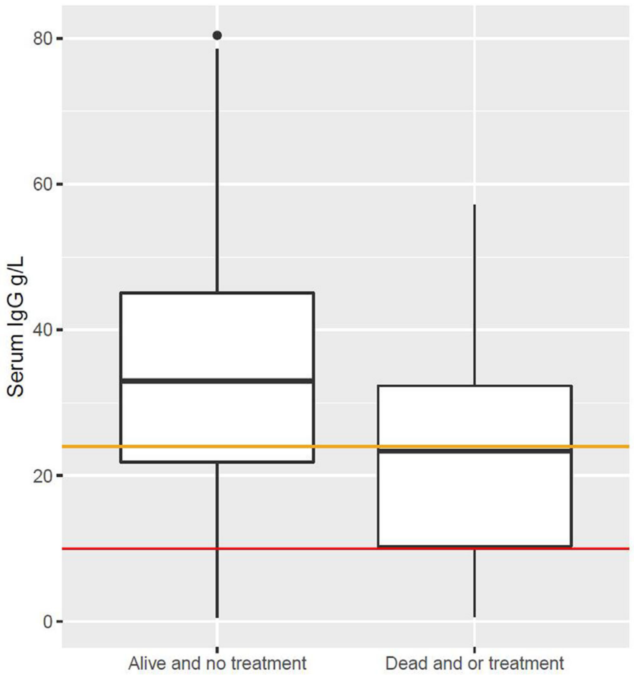

FIGURE 2 Calf outcome (Alive and no treatment [$n = 624$] or Dead and/or treatment [$n = 51$]) versus serum IgG (s[IgG]). Thresholds of 10 and 24 g/L s[IgG] are displayed as the red and yellow lines, respectively

small number of animals in each respective category (numbers provided in Table 5).

DISCUSSION

Calves are the primary source of income for a beef enterprise unit, and as such the outcome of these animals is the critical concern for any beef farmer.[14] This study attempted to try and identify predictive events at the start of a calf's life that could have negative effects on calf outcomes, including morbidity, mortality and ADLWG.

Maximising the weight of calf weaned per kilogram of cow is increasingly being used as a benchmark for suckler beef farms to target.[14] As such, the predictors of ADLWG are important factors to consider. While the preliminary univariable analyses agreed with previous work in that s[IgG] had no significant relationship with ADLWG in the preweaning period,[4] it also agreed with a previous study showing that calf sex, calf birthweight and calf breed affect ADLWG,[4] as shown in Figure 1. However, when controlling for other variables in the multivariable analysis, s[IgG] was significant in all three models, despite the likely wide differences in management between the 50 commercial farms in this study. No further information was gathered about the management of these calves on-farm during the preweaning period in terms of management differences before weaning, including castration, housing type and creep feeding, all of which could potentially have had an effect on the growth of the calves. It would also be difficult to control for all of these confounding variables given the small numbers of farms likely to be in each category, although the 'farm growth rate' was used to define ADLWG according to the different farm-specific management practices encountered in this study. There are also likely to be differences in the methods and accuracy of weighing on-farm, which were not recorded as part of the questionnaire. Despite these likely differences in farm type and weighing methodology, postcolostral calf s[IgG] still came out as a significant explanatory variable for ADLWG in all three multivariable models, showing the long-lasting effects of FPT on suckler calf growth rates.

Dam parity also came out as significant in two of the three ADLWG multivariable analyses, as shown in Figure 1 (panel c). Heifers will generally have smaller calf birthweights (although this would have been controlled for in our multivariable models), produce less volume of milk and the quality of their colostrum and/or milk can be lower in terms of composition,[15] all of which might be expected to affect ADLWG in their calves.

In terms of calf outcomes (morbidity and mortality), the findings from this paper agree with the majority of previously published studies. Male calves (OR 3.74) and calves that required assistance at calving (OR 2.78) are at significantly increased risk of dying and/or requiring some form of treatment in the time between birth and weaning. Male calves being more likely to require treatment and/or die has been found in both beef and dairy studies previously.[16] One study on dairy calves found that only male calves were at significantly higher odds of requiring treatment for any disease on all of their study farms; however, dystocia scores were not measured in that study.[17] The same study reported that sTP was the only variable significantly associated with the odds of mortality in their calf population.[17] The results of our study are noteworthy in that the increased risk of death and/or treatment was observed for bull calves even when the increased risk of dystocia had been controlled for.[12] However, we cannot determine whether this a biological effect or one due to management interventions such as castration. Calf serum IgG was significant for calf outcome as a continuous variable in this study, and the OR for this showed that for every 5 g/L s[IgG] increase, there was a reduced odds of 0.86 for disease treatment or death before weaning.

Combining the calf outcomes of death and/or treatment was performed to increase the power of the statistical analysis, given the relatively small percentage of calves that were reported as dead or treated. Both mortality and morbidity are negative outcomes for farm profitability, and so combining these outcomes retains relevance with respect to the practical application of this work. For treatment and death to be separated into two discrete outcomes, there would have needed to be a much higher number of treatment/death incidents. The combined category of 51/674 calves (7.6%) requiring treatment and/or having died is broken down into a 1.5% mortality rate (10/674 calves) and a 6.4% (43/674 calves) morbidity (treatment) rate. This is much lower than in comparable studies, with an Irish study describing a treatment rate of 20% in beef calves from birth to

6 months of age.[18] One Canadian study described an 18% treatment rate and a 3.1% mortality rate in the first 3 months of life,[3] while another Canadian study reported a 48.1% treatment rate preweaning in a group of 77 calves and three deaths preweaning (3.9% mortality rate).[19] A UK-based study on a beef from dairy calf rearing unit described a 33.5% treatment rate in purchased calves preweaning, with a lower incidence of disease postweaning, and a mortality rate of 1.3%, which was too low to allow for statistical analysis (5/381 calves died).[6] A recent UK study using the national cattle register found an on-farm calf mortality rate of 3.87% by 3 months of age, with a 'non-dairy' (i.e., purebred beef and beef cross-dairy calves) mortality rate of 2.86%.[16]

It is important to note that our data do not include death and treatment in the immediate neonatal window, with the first 24–48 hours after birth known to represent a significant proportion of overall calf mortality and morbidity. The purpose of our study was not to characterise the overall rates of calf mortality and morbidity in British suckler herds, but to understand the impact of calf passive transfer status on preweaning outcomes. As such, our data collection and analysis focused on events following the assessment of calf colostral status. Our findings may also reflect a level of bias in the subpopulation of return information that we received, and it may be that farms with lower morbidity and mortality are more likely to accurately record data and hence be included in our analysis.

There are a number of differing thresholds used in the literature for defining FPT in dairy and beef calves. While s[IgG] below the 24 g/L threshold has been shown to be associated with increased morbidity and mortality in beef calves,[3,4] there appears to be greater consensus on the use of 10 g/L as a threshold for the definition of 'complete' FPT in dairy calves, equivalent to an sTP threshold of less than 51 g/L.[2] This study has shown that both thresholds are valid when assessing beef calf morbidity and mortality, and fits with the concept of 'partial' and 'complete' FPT, and the use of multiple categories for the assessment of calf s[IgG] rather than one single threshold.[2]

This study represents the largest GB-based study gathering data from multiple beef suckler farms under commercial management systems, as opposed to prospective research trials. The follow-up data were gathered by voluntary farmer return, and provide strong evidence for the long-term harmful consequences of FPT in suckler beef calf systems on morbidity, mortality and ADLWG, all of which will harm beef suckler unit profitability. While research and knowledge transfer have traditionally focused on the effects of FPT in dairy herds, this work shows that similar attention is required to minimise the prevalence and consequences of FPT in beef suckler herds.

AUTHOR CONTRIBUTIONS

All authors contributed substantially to this manuscript. Rachel Bragg acquired the data, analysed and interpreted the data and drafted the manuscript. Elizabeth Burrough and Geraldine Russell assisted with data collection and revision of the manuscript. Alexander Corbishley, Samantha Lycett and Alastair Macrae made substantial contributions to conception and design of the study, data interpretation and revision of the manuscript for important intellectual content.

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CONFLICT OF INTEREST

The authors declare that they are not aware of any potential sources of conflict of interest.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request. For the purpose of open access, the authors have applied a CC by public copyright licence to any Author Accepted Manuscript version arising from this submission.

ETHICS STATEMENT

All animal work was approved by the R(D)SVS Veterinary Ethical Review Committee (Reference 102-17).

REFERENCES

1. Lopez AJ, Heinrichs AJ. The importance of colostrum in the newborn dairy calf. J Dairy Sci. 2022;105(4):2733–49.
2. Lombard J, Urie N, Garry F, Godden S, Quigley J, Earleywine T, et al. Consensus recommendations on calf- and herd-level passive immunity in dairy calves in the United States. J Dairy Sci. 2020;103(8):7611–24.
3. Waldner CL, Rosengren LB. Factors associated with serum immunoglobulin levels in beef calves from Alberta and Saskatchewan and association between passive transfer and health outcomes. Can Vet J. 2009;50(3):275–81.
4. Dewell RD, Hungerford LL, Keen JE, Laegreid WW, Dee Griffin D, Rupp GP, et al. Association of neonatal serum immunoglobulin G1 concentration with health and performance in beef calves. J Am Vet Med Assoc. 2006;228(6):914–21.
5. Wittum TE, Perino LJ. Passive immune status at postpartum hour 24 and long-term health and performance of calves. Am J Vet Res. 1995;56(9):1149–54.
6. Caldow GL, White DG, Kelsey M, Peters AR, Solly KJ. Relationship of calf antibody status to disease and performance. Vet Rec. 1988;122(3):63–5.
7. Donovan GA, Dohoo IR, Montgomery DM, Bennett FL. Associations between passive immunity and morbidity and mortality in dairy heifers in Florida, USA. Prev Vet Med. 1998;34:31–46.
8. Windeyer M, Leslie K, Godden S, Hodgins D, Lissemore K, LeBlanc S. Factors associated with morbidity, mortality, and growth of dairy heifer calves up to 3 months of age. Prev Vet Med. 2014;113(2):231–40.

9. Pithua P, Aly SS. A cohort study of the association between serum immunoglobulin G concentration and preweaning health, growth, and survival in Holstein calves. Int J Appl Res Vet Med. 2013;11(1):77–84.
10. Lora I, Gottardo F, Contiero B, Dall Ava B, Bonfanti L, Stefani A, et al. Association between passive immunity and health status of dairy calves under 30 days of age. Prev Vet Med. 2018;152: 12–5.
11. Raboisson D, Trillat P, Cahuzac C. Failure of passive immune transfer in calves: a meta-analysis on the consequences and assessment of the economic impact. PLoS One. 2016;11(3):e0150452.
12. Bragg R, Macrae A, Lycett S, Burrough E, Russell G, Corbishley A. Prevalence and risk factors associated with failure of transfer of passive immunity in spring born beef suckler calves in Great Britain. Prev Vet Med. 2020;181:105059.
13. The R Project for Statistical Computing 2018. The R Foundation. Accessed March 27, 2019. http://www.R-project.org
14. QMS. A guide to improving suckler cow fertility. Quality Meat Scotland; 2017. Accessed November 28, 2022. https://www.qmscotland.co.uk/guide-improving-suckler-herd-fertility
15. Conneely M, Berry DP, Sayers R, Murphy JP, Lorenz I, Doherty ML, et al. Factors associated with the concentration of immunoglobulin G in the colostrum of dairy cows. Animal. 2013;7(11):1824–32
16. Hyde RM, Green MJ, Sherwin VE, Hudson C, Gibbons J, Forshaw T, et al. Quantitative analysis of calf mortality in Great Britain. J Dairy Sci. 2020;103(3):2615–23.
17. Glover ID, Barrett DC, Reyher KK. Little association between birth weight and health of preweaned dairy calves. Vet Rec. 2019;184(15):477.
18. Todd CG, McGee M, Tiernan K, Crosson P, O'Riordan E, McClure J, et al. An observational study on passive immunity in Irish suckler beef and dairy calves: tests for failure of passive transfer of immunity and associations with health and performance. Prev Vet Med. 2018;159:182–95.
19. Homerosky ER, Timsit E, Pajor EA, Kastelic JP, Windeyer MC. Predictors and impacts of colostrum consumption by 4 h after birth in newborn beef calves. Vet J. 2017;228:1–6.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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