

ORIGINAL RESEARCH

Associations between small ruminant lentivirus infection and total milk yield and somatic cell count in a dairy sheep flock

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Abstract

Background: Small ruminant lentiviruses (SRLVs) are lentiviruses of sheep and goats, formerly known as maedi-visna (MV) in sheep and caprine encephalitis and arthritis in goats. In sheep, SRLVs commonly cause progressive pneumonia, wasting and indurative mastitis. SRLVs have a long latent period, and chronic production losses are often not recognised until very late. Few studies quantifying the production losses in ewes have been published, and none have been published under UK flock husbandry conditions.

Methods: Production records of milk yield and somatic cell count (SCC) from a dairy flock of 319 milking East Friesian × Lacaune ewes identified as MV infected via routine serological screening for SRLV antibodies were used in multivariable linear regression modelling to estimate the impact of SRLV status on total milk yield and SCC.

Results: Milk yield was reduced in seropositive ewes by 8.1%–9.2% over an entire lactation. SCC counts were not significantly different in SRLV-infected and uninfected animals.

Limitations: Further parameters, such as body condition score or clinical mastitis, that were not available may have clarified the underlying cause of milk yield drop.

Conclusions: The study demonstrates substantial production losses in an SRLV-affected flock and highlights the impact of the virus on a farm's economic viability.

KEYWORDS

Maedi-Visna, milk, sheep, small ruminant lentivirus

INTRODUCTION

Small ruminant lentiviruses (SRLVs) are an overlapping group of lentiviruses affecting sheep and goats. Major routes of spread are by either colostrum or respiratory transmission; infection typically causes chronic interstitial pneumonia and indurative mastitis in sheep and arthritis in goats. Encephalitis can occur but is not a common presentation in the UK.¹ The viruses integrate into the DNA of infected monocytes and have a long latent period in which they are present at a low level and difficult to detect via molecular or serological methods. When the monocytes become activated and differentiate into macrophages

(usually in tissues in response to infection), the virus also becomes activated and is produced at high levels.² Following this, it may then take several years before clinical manifestations of disease (which in sheep often presents as chronic wasting) are apparent. SRLVs are also hypervariable, and to date, there has been little success in developing PCR or qPCR-based diagnostics capable of detecting all (or even most) virus variants. Current testing relies on serology to detect antibodies against a mix of virus Gag and Env proteins³ and displays a considerable lag before animals test positive following natural infection (mean seroconversion occurring at 3–8 months after infection).⁴

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This combination of factors makes SRLVs difficult to detect and control, meaning that infections are often not detected until a high proportion of the flock is infected and/or advanced, severe clinical cases are present.^{5,6} Chronic production losses are by their very nature insidious, progressive and often go undetected.⁷

Some of the main economic impacts of SRLV infections are reductions in the number of lambs reared, birth weights or growth rates of lambs, and increased mortality rates.^{7–9} In addition to these, the impact on milk yield has been investigated in both sheep and goats, but with varying results. Estimates of total milk production losses in goats vary from not significant to 22.7%,^{10–16} while milk production estimates in sheep vary from an increase of 18% to a decrease of 30%.^{17–21}

Multiple factors have been identified as playing a role in milk yield changes in infected animals, such as SRLV-induced mastitis and reduced lactation periods.^{14,22,23} It has also been suggested that lower growth rates observed in lambs infected with SRLV can be attributed in part to reduced milk yields and indurative mastitis associated with infection.²⁴

Measurement of somatic cell count (SCC, mostly macrophages, leukocytes and lymphocytes) in milk is a common proxy method for estimating mastitis (bacterial or viral infection) levels in ruminants. The threshold values proposed for differentiating healthy and infected ewes lie within the range of 250–500 × 10³ cells/mL.²⁵ Similar to the situation with milk yield studies, reports of the impact of SRLVs on SCC vary, with Lipecka et al.¹⁸ and Ryan et al.²⁶ reporting a significant increase in SCC in sheep and goats, respectively, and Turin et al.²⁷ and Kaba et al.¹³ reporting no significant change in goats.

The aim of this study was to quantify the impact of SRLV infection on milk yield and SCC within a dairy flock of 319 East Friesian × Lacaune ewes managed under UK production conditions.

MATERIALS AND METHODS

Animals

Individual milk samples were collected from a commercial UK flock of 319 dairy East Friesian × Lacaune ewes in July 2017. The sampling point represented the approximate mid-point in lactation for the flock that commenced lambing in March and was dried-off in batches from mid-October to mid-November according to their point at which their daily milk yield fell below 500 mL. Any ewes still producing more than 500 mL in mid-November were dried-off regardless of milk yield. Samples were analysed for antibodies to maedi-visna virus (MVV) by the Scottish Agricultural College Diagnostics Service, St Boswells, UK, using the ELITEST-MVV/CAEV (HYPHEN BioMed), a recombinant ELISA using the capsid p28 core protein and a peptide derived from the immunodominant region of the viral transmembrane envelope protein gp46. Differentiation of seropositive and seronegative ewes was

carried out as recommended by the manufacturer, using an optical density threshold of 0.6 for confirmation of positivity. The same samples underwent SCC analysis by Quality Milk Management Services, Wells, UK.

Ewes were introduced into the milking flock as soon as lambs were removed (ie, at 48 hours after birth) and milk yield recording was conducted at every milking. The milking flock was managed as one group throughout lactation. Milk yield records were collected daily throughout lactation by an automated milk meter system integrated into the parlour management system (DeLaval—DelPro3.0).

Lambs were allowed to suckle for 48 hours after lambing, after which point the lambs were removed and reared artificially on an automatic machine and powdered whey-based milk replacer. Surplus male and female lambs were sold between 10 and 26 weeks for meat. Ewe lamb replacements were reared apart from the milking flock until their first lambing at 2 years old. A small number of ram lambs from high-merit ewes are retained for line breeding. The flock is managed as a closed unit with no purchase of live animals. New genetics are introduced periodically by artificial insemination.

Statistical modelling

Descriptive and multiple linear regression model analysis was carried out using Minitab19. The primary outcome, the dependent variable of interest, was the total milk yield during lactation. To estimate the relative influence of MVV infection status and predict percentage increase or decrease in the total lactation milk yield, a multiple linear regression model was constructed with all available independent variables. Mid-lactation SCC was coded as a continuous variable, natural log and log¹⁰ transformation, to compare model fit with no significant impact upon final model outcomes. Parity and MVV status were coded as categorical variables, with negative status as the reference value. Daily automated milk records were aggregated to calculate the total milk yield in lactation, with days in milk included in the model to account for variation in lactation length. Collinearity was low, with variance inflation factor scores all less than 1.35. Model fit was assessed graphically and data are provided in [Supporting Information](#).

RESULTS

The apparent prevalence of MVV infection as determined by the threshold of the assay was 22% (70 of 319). The parity structure was calculated as a proportion of the entire flock, and the MVV prevalence within each parity is displayed in Table 1. Distributions (interquartile range around the median) of milk yield and SCC by MVV assay test result (positive/negative) for each parity group within the flock are also detailed in Table 1. The distributions of

TABLE 1 Distributions of milk yield and somatic cell count (SCC) by maedi–visna virus (MVV) assay test result (positive/negative) for each parity group within the flock along with the prevalence of MVV-positive antibody titre results by parity group

Parity	Proportion of the flock	MVV prevalence within parity group	Total lactation yield (L) and median (IQR) by MVV test result				Mid-lactation SCC (1000 cells/mL) and median (IQR) by MVV test result			
			MVV positive		MVV negative		MVV positive		MVV negative	
1	33%	16%	247	64	271	80	118	156	143	262
2	15%	11%	281	62	299	63	75	110	153	154
3	17%	33%	262	58	320	59	82	100	103	195
4	24%	26%	265	103	298	75	79	130	82	122
5	6%	32%	273	60	303	26	101	235	50	62
6 and above	5%	25%	185	66	250	53	102	111	89	51

Note: Medians are presented together with the interquartile range (IQR) around the median.

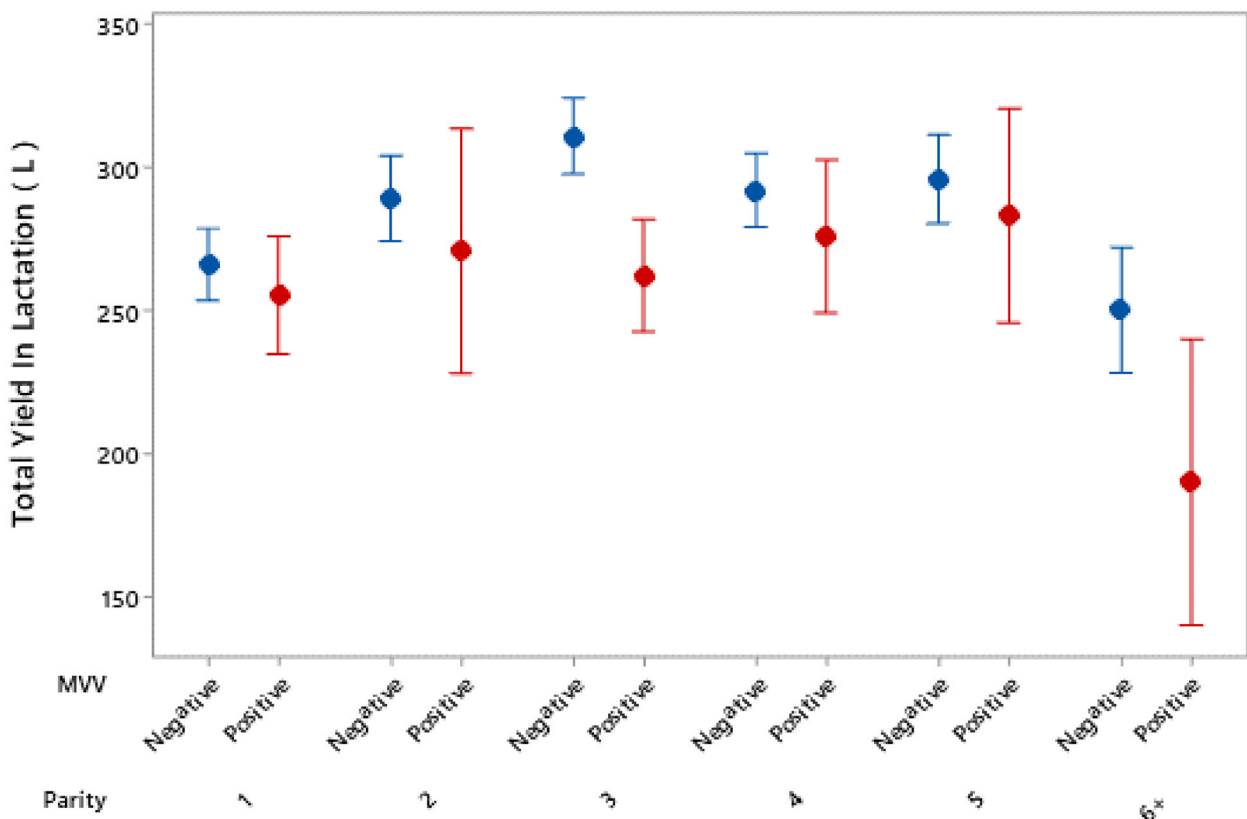


FIGURE 1 Distribution of total milk yield in the lactation expressed as 95% confidence interval of the mean yield by parity and maedi–visna virus (MVV) test result status (positive: red; negative: blue)

parities for animals classified as MVV infected by the test were significantly older than those classified as uninfected, although infected ewes were identified in all parity groups ($p = 0.02$). The distributions of SCC did not differ significantly with either parity or MVV infection status (Table 1). As expected, milk yields in MVV-negative parity 1 animals and old (parity 6) animals were less than those of animals in parity 2–5. MVV-positive ewes produced less milk on average than their MVV-negative flock mates in each parity cohort; the reduction was most marked in parity 6 ewes (Figure 1). Mid-lactation SCC was not associated with total milk yield in the lactation period in this model, whereas MVV-positive status was associated with a median reduction in milk yield of 24.73 L

(Table 2). This equates to a predicted percentage reduction in total milk yield of between 8.1% and 9.2%.

DISCUSSION

This study reports milk yield production losses due to SRLV infection of 8.1%–9.2%. Previous estimates of milk production losses in dairy sheep and goats vary considerably from not significant to 30%; however, a variety of breeds, production systems and recording systems have been used across studies.^{10–21} The results of this study support the findings of previous studies in Spanish and Polish sheep production systems,^{18,20,21} which are either experimental

TABLE 2 Multiple linear regression model of total milk yield during lactation (L), parity, maedi–visna virus (MVV) test status and mid-lactation somatic cell count (SCC)

Term	Coefficient	SE coefficient	95% CI	p-Value
Constant	267.98	5.04	(258.06, 277.90)	0.000
Mid-lactation SCC	-0.00044	0.00277	(-0.00590, 0.00501)	0.873
Parity (ref = 1)				
2	22.11	8.68	(5.03, 39.18)	0.011
3	35.29	8.29	(18.98, 51.61)	0.000
4	26.99	7.51	(12.21, 41.77)	0.000
5	31.8	12.3	(7.6, 56.1)	0.010
6	-26.6	13.2	(-52.7, -0.6)	0.045
MVV status (ref = negative)				
Positive	-24.73	6.82	(-38.14, -11.31)	0.000

Abbreviation: CI, confidence interval.

studies¹⁸ or retrospective studies with similar design and analysis methods to our study.^{20,21} On the basis of this evidence, the authors believe it is reasonable to conclude that milk production in dairy ewes can be expected to be reduced by at least 5%, up to potentially over 10% during the early mid-phase of the disease process when animals are seropositive but pre-clinical and not showing any overt signs of respiratory disease. It is unclear whether the degree of milk yield reduction observed in this and other studies of dairy ewes would be replicated in suckler lamb-producing sheep flocks, which typically have a lower milk yield but are also managed at a lower and more variable plane of nutrition and are more genetically diverse than the dairy sheep population.

Both milk yield and MVV infection status varied with parity status. It is to be expected that first parity ewes and aged ewes will have a reduced milk yield compared to mid-age range animals as this is a normal production pattern by age.²⁸ Similarly, it is expected that aged ewes in an MV-positive flock will have a higher rate of positivity than younger ewes, as the disease has a long latent period, with animals more likely to test positive and show clinical signs as they age.⁴ Both effects were seen in this study, alongside a consistent drop in milk yield in MV-positive animals in each parity, with the effect more marked in the oldest animals.

The findings of this study would suggest that SCC is not a reliable predictor of MVV infection; indeed, in this study, the range of SCC was not outside the normal range of 200–500 × 10³ cells/mL.²⁵ This cross-sectional study design is not able to determine if the temporal patterns in SCC differ between seropositive and seronegative ewes as they progress through lactation and the disease course of one or more lactations. While the negative impact on milk production is evident, the mechanism is not clear. The type of mastitis induced by MVV is described as indurative and is characterised histologically by infiltration of lymphocytes and macrophages into the interstitium of the mammary gland. Particularly in the earlier stages of disease, this

may not result in the excess shedding of inflammatory and epithelial cells into the milk that is measured by SCC.^{29,30} Alternatively, MVV-infected ewes will also be experiencing subclinical cardiorespiratory impairment due to slowly developing pneumonia (the primary pathology in MV infections) with a resultant impact on metabolic efficiency, which manifests itself as a reduced milk yield. These hypotheses may have been supported if additional parameters had been measured, such as body condition score and/or liveweight, or histological studies of mammary glands from culled ewes to correlate with SCC and MVV status had been performed. Due to the nature of the clinical study in a commercial flock, this was not feasible in this study.

CONCLUSIONS

The results of this study show that under typical UK dairy flock management conditions MVV infection is associated with a significant and substantial drop in milk production. This concurs with findings of similar studies in a diverse range of production systems. This is an economically significant issue for a low-margin farming system in the case of dairy ewe production and potentially for suckler lamb producers if similar magnitudes of milk production loss are seen in response to MVV infection, and those losses translate into reduced lamb growth rate. This and other studies emphasise the economic imperative to quantify and control the impact of MV and other iceberg diseases such as ovine Johnes' disease.^{7,8}

AUTHOR CONTRIBUTIONS

Peers Davies and Rachael E. Tarlinton secured funding for the PhD studentship. Rachael E. Tarlinton supervised students with input from Stephen Dunham and Peers Davies. Peers Davies liaised with the farmer, collected the data and conducted the statistical analysis. Scott Jones wrote the literature review. All authors contributed to and edited the manuscript.

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CONFLICT OF INTEREST STATEMENT

None of the authors has any other financial or personal relationships that could inappropriately influence or bias the content of the paper.

DATA AVAILABILITY STATEMENT

The raw data supporting this paper are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

The study was approved by the University of Nottingham School of Veterinary Medicine and Science Committee for Animal Research and Ethics.

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SUPPORTING INFORMATION

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

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