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Spirometric performance in Belgian Blue calves: I. Effects on economic losses due to the bovine respiratory disease complex

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ABSTRACT: The aim of this study was to determine whether high spirometric performances in calves are associated with low economic losses due to the bovine respiratory disease complex (BRDC). Five spirometric variables (SV) were measured in 909 double-muscle Belgian Blue calves from 15 to 60 d of age. Afterward, calves were monitored for 6 mo to determine whether they developed BRDC and to determine the costs due to BRDC (i.e., medicine costs and veterinarians' fees, plus estimated financial losses due to mortality in case of death). To analyze the effects of spirometric perfor-

mances on BRDC cost, a fixed linear model was used for each SV. In addition to SV, each model included the effects of sex, dam's parity, vaccination status, muscular development score, herd-period, and BW. Only herd-period and the maximal ventilation and the vital capacity had significant effects on costs due to BRDC, indicating that these two SV are major physiological determinants of economic losses associated with BRDC. Accordingly, it is assumed that an amelioration of maximal ventilation and vital capacity could result in increased resistance to BRDC in calves.

Key Words: Calves, Economic Impact, Lung Function, Respiratory Diseases

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Introduction

The bovine respiratory disease complex (BRDC) is reported to be the major cause of financial losses due to infectious diseases in calves (Scott et al., 1996; Griffin, 1997). Mortality, impaired performance caused by irreversible pulmonary lesions, and high costs of therapeutic interventions explain the important economic impact of BRDC.

Heritability of BRDC occurrence is low, ranging from 0.01 to 0.11 (Lyons et al., 1991; Muggli-Cockett et al., 1992), suggesting that selection for more resistant animals using BRDC occurrence as a selection criterion would be very slow. In human and veterinary medicines, measurement of spirometric variables (SV) is used to estimate the efficiency of the respiratory function of patients (Taylor et al., 1989; Bureau et al.,

1999a). Human patients with high SV are more likely to avoid respiratory failure in exacerbation of pulmonary diseases compared with patients with low SV (Beachey and Olson, 1990). This observation led us to hypothesize that amelioration of spirometric performances could result in increased resistance to BRDC in calves and that selection for increased SV could be a way to improve these performances. To verify these hypotheses, it was essential 1) to determine whether an association between high SV and resistance to BRDC exists in calves and 2) to estimate the genetic parameters for SV.

Therefore, two separate studies were designed. The objective of the first study, which is presented in the present paper, was to determine whether high SV in calves are associated with low economic losses due to BRDC. The second study, which will be presented elsewhere, was devoted to the estimation of genetic parameters for SV.

Materials and Methods

Animals and Data Collection. This study was approved by the Ethical Committee of the University of Liège.

Spirometric variables were measured in 909 double-muscle Belgian Blue calves (432 males and 477 females, 15 to 60 d of age, weighing 33 to 135 kg) in 79 herds between August 16 and November 15, 1997. No

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animals exhibited signs of disease upon pre-experimental clinical examination or had history of respiratory disease. A period of feed withdrawal was imposed for at least 6 h before SV measurements and weighing.

Calves were given a muscular development score ranging from 1 (moderately muscled calves) to 5 (extremely muscled calves). Test dates, calves' sex, and dams' parity were recorded. Test dates were congregated into four test periods with similar numbers of records: from August 16 to September 15 (test period 1, $n = 236$), from September 16 to September 30 (test period 2, $n = 198$), from October 1 to October 15 (test period 3, $n = 278$), and from October 16 to November 15 (test period 4, $n = 197$). Data on herds and test periods were consolidated into 100 herd-periods with a minimum of five records per herd-period. Parity numbers were grouped into primiparous and multiparous cows. Some calves were vaccinated against bovine adenovirus type-3, bovine herpes virus type-1, parainfluenza-3 virus, and bovine respiratory syncytial virus when they were 3 mo of age. These calves were considered as "vaccinated" and the other calves as "nonvaccinated."

After measurement of SV, calves were monitored for 6 mo to determine whether they developed BRDC. Bovine respiratory disease complex was always diagnosed by a veterinarian and was indicated by labored or rapid breathing associated with either cough, nasal discharge, fever, anorexia, or adventitious lung sounds on auscultation. A specific diagnosis was not usually obtained. The choice of medicines used for BRDC treatment was left to the veterinarians' judgment. However, the cost of each medicine and fees for veterinary services were standardized and subsequently did not differ among herds. When a calf developed BRDC, the costs of veterinary treatments (i.e., medicines and veterinarians' fees) were recorded by the veterinarian. When a calf died of BRDC, the economic loss due to mortality was estimated by an experienced technician and added to the costs of veterinary treatments. Revenue losses resulting from reduced growth rate were not considered in this study. To ensure that data were scrupulously recorded, each herd and each veterinarian was visited biweekly. Costs due to BRDC were expressed in EURO (contemporary exchange rate: 1.00 EURO \cong US\$ 0.83).

Measurement of SV. Each calf received a single i.v. dose of lobeline (0.25 mg/kg, Lobelin, Boehringer Ingelheim, Ingelheim, Germany) (see Bureau et al., 1999a, for more technical details). Ventilatory variables (i.e., respiratory frequency [min^{-1}], tidal volume [L], ventilation [L/min], and peak expiratory and inspiratory flows [L/s]) were all measured at rest and continuously from injection time until complete recovery.

The respiratory flow was measured with a heated Fleisch pneumotachograph No. 3 mounted on an airtight face mask and coupled to a differential pressure transducer (Validyne DP45-14, Validyne Engineering, Northridge, CA) with two identical catheters. The PoNeMah system (Gould Instrument Systems, Valley

View, OH) was used to derive ventilatory variable values from flow measurements on each artifact-free respiratory cycle. The PoNeMah system was calibrated by forcing a known volume of air (0.5 L) through the pneumotachograph. Linearity and symmetry of airflow measurements were tested with a flow rotameter suitable for measuring flow rates from 1 to 16 L/s.

For each calf, the following SV were calculated: **15-s MV_L** , average ventilation recorded during the 15 s of maximal ventilatory changes induced by lobeline administration; **VC_L** , **$MPEF_L$** , and **$MPIF_L$** , vital capacity, maximal peak expiratory flow, and maximal peak inspiratory flow recorded after lobeline administration, respectively; and **VR_L** , ventilatory reserve ($VR_L = 15\text{-s } MV_L - \text{ventilation at rest}$).

Statistical Analysis. A logarithmic transformation was applied on BRDC costs to obtain data more normally distributed than original data [$Lcost = \ln(\text{cost} + 2 \text{ EURO})$]. To correctly estimate the effects of SV on Lcost, it was necessary to assess simultaneously the effects of different fixed variables affecting Lcost, and therefore to use fixed linear models (GLM procedure of SAS, SAS Inst. Inc., Cary, NC). Each model included the effects of one of the five SV and the effects for sex (male vs female), dam's parity (primiparous vs multiparous), vaccination status (vaccinated vs nonvaccinated), muscular development score ($n = 5$), herd-period ($n = 100$), weight as a linear covariable, and all first-order interactions. Because preliminary analyses showed that only the interaction between muscular development score and vaccination status significantly influenced Lcost, only this interaction was included in the final models used to obtain least squares means estimates. $P < 0.05$ was considered significant and $P < 0.01$ was considered highly significant.

Results and Discussion

Descriptive Statistics. Of the 909 animals included in the analysis, 328 (36%) were treated for BRDC during the experimental period. Nineteen (2.1%) calves died because of respiratory disorder. The average financial loss over all 909 calves was estimated at 23.35 EURO. The cost of medicines, veterinarians' fees, and economical losses due to calves' death averaged 10.97, 4.20, and 8.17 EURO, respectively. The average economic loss per morbid animal was estimated at 64.71 EURO. Bovine respiratory disease complex was much more prevalent, severe, and costly in this study than in any other published survey. For instance, Muggli-Cockett et al. (1992) observed a morbidity rate of 23.9% and a mortality rate of 1.4% in beef calves during their 1st yr of life. In another study, overall costs of BRDC were estimated at \$14.71 per calf year (Kaneene and Hurd, 1990). The high incidence and severity of BRDC reported in our study could be attributed to the lower resistance to BRDC of hypermuscled calves less than 1 yr of age compared to dairy calves (Dive, 1982).

Statistical Analysis. The herd-period effect on BRDC cost was highly significant in any of the five models used. For instance, in the model used for VC_L , the partial R^2 based on type I SSQ was 82.32 % for the herd-period effect. It is likely that this important effect was due to the fact that herd-related factors that contribute to BRDC development were differently managed among farms and varied with time. These management factors have been previously reviewed by Scott et al. (1996) and include diet, air quality, temperature and humidity in the sheds, number of animals per available space, physical stresses, rapidity of disease detection, and so on. In this study, the choice of medicines used to treat diseased calves was left to the practitioners' judgment. Accordingly, differences in choice of medicines among farms probably contributed to the effect of herd-period on BRDC cost.

The effects of sex, dam's parity, vaccination status, muscular development, and weight on BRDC cost were not significant in any of the five models used. The least squares means estimates obtained from the model including VC_L as the independent SV were similar to least squares means estimates obtained with models including other SV and are shown in Table 1. As reported in other studies (Waltner-Toews et al., 1986; Sivula et al., 1996), the calves investigated in the present report were generally affected by BRDC before the age of vaccination (i.e., 3 mo of age), with peak incidence occurring at approximately 2.5 mo. Although this observation explains the fact that vaccination had no effect on BRDC cost in our study, this does not necessarily mean that vaccination is ineffective. Indeed, vaccination protected Belgian Blue calves older than those studied in the present report (i.e., calves from 6 mo to

Table 1. Costs due to bovine respiratory disease complex in Belgian Blue calves. Least squares means and standard errors for each category of sex, dam's parity, vaccination status, and muscular development

Category	n	Lcost, EURO
Sex		
Male	432	2.94 ± 0.14
Female	477	2.84 ± 0.13
Dam's parity		
Primiparous	324	2.93 ± 0.16
Multiparous	585	2.85 ± 0.12
Vaccination status		
Vaccinated	333	2.84 ± 0.13
Nonvaccinated	576	2.94 ± 0.17
Muscular development score		
1 (Moderately muscled)	101	2.92 ± 0.30
2	155	3.20 ± 0.23
3	386	3.02 ± 0.13
4	189	2.71 ± 0.21
5 (Extremely muscled)	78	2.63 ± 0.37

Lcost = $\ln(\text{cost} + 2 \text{ EURO})$. There were no significant differences between means.

Table 2. Linear regression coefficients (b) and standard errors (x) of five spirometric variables on costs due to bovine respiratory disease complex in Belgian Blue calves, after adjusting for the effects of sex, dam's parity, vaccination status, muscular development score, herd-period, weight, and muscular development score × vaccination status interaction^a

Spirometric variable	b(x)	P-value
15-s MV_L	-0.012 ± 0.006	0.035
VC_L	-1.001 ± 0.334	0.003
$MPEF_L$	-0.097 ± 0.084	0.248
$MPIF_L$	-0.027 ± 0.097	0.784
VR_L	-0.010 ± 0.012	0.067

^aCosts were converted to logarithms ($\ln(\text{cost} + 2 \text{ EURO})$). 15-s MV_L , average ventilation recorded during the 15 s of maximal ventilatory changes induced by lobeline administration; VC_L , $MPEF_L$, and $MPIF_L$, vital capacity, maximal peak expiratory flow, and maximal peak inspiratory flow recorded after lobeline administration; VR_L , ventilatory reserve ($VR_L = 15\text{-s } MV_L - \text{ventilation at rest}$).

1 yr of age) from mortality due to bovine respiratory syncytial virus (Dive, 1982).

The effects of $MPEF_L$, $MPIF_L$, and VR_L on the costs due to BRDC were not significant (Table 2). Conversely, 15-s MV_L and VC_L had significant and highly significant effects on BRDC cost, respectively (Table 2). For instance, in the model used for VC_L , the partial R^2 based on type I SSQ was 15.85% for VC_L . A decrease of -1.001 in Lcost was observed for each linear increase in 1 L of VC_L . Similarly, a drop of -0.012 in Lcost was observed for each linear increase in 1 L/min in 15-s MV_L .

Physiological variables that influence $MPEF_L$ are upper airway resistance and pulmonary resistance, whereas $MPIF_L$ is mainly reliant on extrathoracic airway resistance and inspiratory muscle strength (see Aldrich et al., 1982 and Bureau et al., 1999b for more details about SV). Conversely, VC_L is dependent on lung size and compliance. Maximal ventilation depends on all the variables affecting $MPEF_L$, $MPIF_L$, and VC_L , (i.e., extra- and intrathoracic airway resistances, inspiratory muscle strength, and lung size and compliance). Accordingly, 15-s MV_L is used to globally evaluate the respiratory function of a patient, whereas $MPEF_L$, $MPIF_L$, and VC_L are useful to determine the precise type of lung dysfunction. In this study, VC_L and 15-s MV_L , unlike $MPEF_L$, $MPIF_L$, and VR_L , had significant effects on the costs due to BRDC, indicating that weak pulmonary size and compliance, but not high airway resistance or weak inspiratory muscle strength, are important physiological determinants of BRDC cost in hypermuscled calves.

Implications

The results of this study show that low vital capacity and maximal ventilation recorded after lobeline administration are associated with increased economic losses

due to bovine respiratory disease complex in hypermuscled calves and reinforce the hypothesis that improvement of these spirometric variables could result in increased resistance to bovine respiratory disease complex. Vital capacity and maximal ventilation could be ameliorated by improving environmental factors affecting these variables or by selecting for enhanced spirometric performances. Accordingly, further studies are needed to analyze environmental factors influencing spirometric variables and to estimate their genetic parameters.

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