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Dairy Calf Management, Morbidity and Mortality in Ontario Holstein Herds. IV. Association of Management with Mortality

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Abstract

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Associations between heifer calf management and mortality were studied on 104 randomly selected Holstein dairy farms in southwestern Ontario between October 1980 and July 1983. At the farm level, data were stratified by season, with two six-month seasons (winter and summer) per year. The odds of farms with particular management strategies having above-median morbidity were calculated. At the individual calf level, the odds of a calf being treated, controlling for farm of origin and month of birth, were calculated for different management practices.

Larger farms had significantly greater odds of experiencing mortality than smaller farms in both winter and summer. Farms which had policies of attending calvings and ensuring that calves received their first colostrum had significantly lower odds of experiencing winter mortality than farms which did not have these policies. Farms which housed calves in hutches had significantly lower odds, and those which housed calves in group pens had significantly higher odds, of experiencing summer mortality, than farms which used individual indoor calf-pens. A policy of teat removal between four weeks of age and weaning was associated with increased odds of summer mortality.

At the individual calf level, calving ease, sire, navel treatment, assistance at first colostrum feeding, administration of vitamins A, D and E and anti-scour vaccines to the pregnant dam, and place of calving, were all associated with significantly altered odds of dying. However, several interactions entered the statistical models, and the effects of those management practices were not all straightforward.

Introduction

The nature and significance of calf morbidity has been and will continue to be debated among animal scientists, dairy farmers, and veterinarians for...
some time. Calf mortality, however, represents an irrefutable and irrevocable financial and genetic loss to the dairy industry. The identification of those factors which can alter a calf's risk of dying is thus an important prerequisite for the design of calf rearing programs.

A number of large field observational studies have been carried out in Europe and North America over the past 30 years (Withers, 1952; Leech et al., 1968; Oxender et al., 1973; Speicher and Hepp, 1973; Staples and Haugse, 1974; Ferris and Thomas, 1975; Martin et al., 1975a; Bowman et al., 1977; Jenney et al., 1981; Simensen, 1982, 1983). Most of these studies suffered from one or more serious design or analytical flaws. These were addressed earlier (Waltner-Toews et al., 1986a). In all fairness, however, it should be pointed out that no practical field study is likely to be ideal, in a statistical or epidemiological sense. Nevertheless the constraints of various studies need to be taken into account when interpreting the results. For dairy farmers in southwestern Ontario, the chief drawback of studies done elsewhere is that it is not known to what extent, if at all, findings from California, or even Michigan, are applicable to the Ontario situation.

The purpose of this study, therefore, was to examine the effect of various management strategies (at the farm level) and various management practices (at the individual animal level) on calf mortality on southwestern Ontario dairy farms.

MATERIALS AND METHODS

This study was based on heifer calf records from 104 randomly selected Holstein dairy farms in southwestern Ontario. All farms were used for farm level analyses. On a random subset of 35 of these farms, individual heifer calf data were collected. These records formed the basis of the individual calf analyses. Data were collected from all farms over a two and one-half year period between 1980 and 1983. Methods of farm selection, data collection, descriptions of management variables and calf outcomes, and the effects of management on morbidity, have been discussed elsewhere (Waltner-Toews et al., 1986a,b).

Farm-level mortality rates were calculated for the following seasonal time periods: 1 January—15 May 1980 (Winter 1); 16 May—15 November 1981 (Summer 1); 16 November—15 May 1982 (Winter 2); 16 May—15 November 1982 (Summer 2) and 16 November—15 May 1983 (Winter 3). Winter 1 was slightly truncated to allow time for all farmers to become accustomed to the record-keeping system. Rates were calculated as (number of heifer calves died) ÷ (number of live-born heifer calves) for each time period. The distribution of these mortality rates was shown previously to follow a non-normal (non-Gaussian) pattern (Waltner-Toews et al., 1986a). In each time period, the median mortality rate was zero, while the mean was around 6%. It was therefore deemed appropriate, both from a statistical
and a practical viewpoint, to divide farms into those experiencing mortality and those not experiencing mortality. Also, all predictor variables considered, except for FARM SIZE, were binary or categorical in nature. Statistical analyses were carried out using stepwise multiple logistic regression to search for management variables which might distinguish the two groups of farms (Kleinbaum et al., 1982). Some variables, such as those concerned with whether or not hutches were moved between calves, or whether or not indoor calf pens were in an air space separate from the adult cows, only applied to particular subsets of farms. These were analyzed by means of two-way tables, stratified by year, with differences tested by chi-square or Fisher's Exact test.

At the individual calf level, stepwise logistic regression was used to analyze data for calves dying between birth and weaning, and also for those dying during the neonatal period (< 28 days). At the individual calf level, all predictor variables, except for estimated birth weight (from heart-girth measurements) were binary or categorical in nature. Data were available for 1968 heifer calves born between the winter of 1980 and the spring of 1983; of these, 3.76% died between birth and weaning. Whereas the main analyses were carried out on the full data set, the effect of estimated birth weight could only be evaluated on 614 calves. Similarly, information on age at removal from dam and subsequent housing was only available for 682 calves.

At both levels of analysis, initial main effects models were run with p-values for F-to-remove and F-to-enter set to 0.15 and 0.10, respectively. The variables selected in the main effects models were used to create other variables denoting interaction. These F values were then set to 0.10 and 0.05 (removal, entry) and interactions involving the variables having significant main effects were assessed, using the hierarchical inclusion rule, namely, an interaction term was only allowed to enter the model if both main effects were already included.

For analyses at the individual calf level, the various categories of calving ease (EASE) were pooled to create a binary variable: assisted calving versus non-assisted calving. Similarly, method of feeding first colostrum (HOW-COLOSTRUM) was re-structured into assisted and/or supplemented versus natural suckle only. This restructuring was carried out primarily to simplify the model and facilitate interpretation of interaction terms. Nevertheless, since both calving ease and method of first colostrum feeding significantly affected the odds of dying, the details of these associations were explored in secondary analyses.

Lemeshow and Hosmer's statistic (1982) was used to assess the fit of the chosen logistic model to the data.

The effects of various within-farm management variables on age at death were assessed using multiple linear regression. Based on the lowest Mallows' Cp statistic, the 'best' subset was chosen from a print-out of all possible subsets (Draper and Smith, 1981; SAS, 1982). This model was then evaluated
further by examination of residuals, as well as the significance of the regression coefficients.

The specific management variables considered for inclusion in the models were discussed in previous papers in this series (Waltner-Toews et al., 1986a, b).

RESULTS

Variables affecting the odds of a farm having above-median mortality rates are displayed in Table I. Within-farm factors affecting individual calf survival to weaning and in the prenatal period ($\leq 28$ days) are shown in Tables II and III, respectively, and are discussed in some detail in the next section. In all cases, only odds ratios significant at $P \leq 0.05$ are shown. For other variables, or levels of variables, only the direction of the effect is shown. A negative sign indicates an odds ratio of $< 1$, that is, a sparing or beneficial effect.

For the subset of 614 calves in which the effect of estimated birth weight

### TABLE I

Calf management factors affecting whether or not Holstein dairy farms in southwestern Ontario experienced heifer calf mortality, 1981–83

| Variable Categories | OR* (95% CL) |
|---------------------|--------------|
| Winter season: 16 November–15 May |
| FARM SIZE | 102^b (1.01, 1.03) |
| HOW-COLOSTRUM | First colostrum assisted or supplemented vs suckle only | 0.38 (0.20, 0.74) |
| OBSERVED CALVINGS | — |
| Summer season: 16 May–15 November |
| FARM SIZE | 1.05 (1.03, 1.07) |
| CALF-HOUSING | Group vs individual pens | 3.91 (1.39, 11.02) |
| | Hutches vs individual pens | 0.23 (0.07, 0.76) |
| | Other vs individual pens | + |
| TEAT-REMOVAL | < 4 wks vs not removed | — |
| | > 4 wks vs not removed | 12.31 (1.69, 89.50) |

*Odds ratio of having above-median rate (zero), controlling for county, year, record-keeping score and weaning age. Figures are only given for odds ratios significant at $P \leq 0.05$. For other variables, or levels of variables, a '+' indicates a mean odds ratio of $> 1$, and a '−' indicates an odds ratio of $< 1$. Lemeshow and Hosmer statistics, p-values: winter = 0.70; summer = 0.364. A larger p-value indicates a better fit of model to the data.

^bOdds ratio for farms that differ by one calving per year.
could be assessed, it was found that this variable did not significantly affect calf survival. The direction of the coefficient ($P \leq 0.15$) indicated an odds ratio of $< 1$, that is, that heavier calves tended to survive better than lighter calves.

Similarly, in the subset of 682 calves in which housing (CALF-HOUSING) and age at removal (REMOVAL-AGE) could be assessed, neither variable exerted a significant ($P \leq 0.05$) impact on calf mortality, although both did enter the logistic model. For CALF-HOUSING, odds ratios of $< 1$ were seen for 'hutches' and 'other' relative to individual pens, and $> 1$ for group pens. Nevertheless this variable became nonsignificant, even at $P = 0.15$, once other variables in the model were controlled for. REMOVAL-AGE remained significant only at $P \leq 0.15$; calves left longer with the dam tended to have an increased probability of dying.

No variables had any significant impact on age at death, although calves born in maternity pens tended ($P = 0.062$) to die younger than calves born elsewhere.

**TABLE II**

| Variable                  | Categories | OR$^a$ (95% CL)          |
|---------------------------|------------|--------------------------|
| EASE$^b$                  | Assist vs no assist | 31.44 (2.88, 343.57)      |
| COW-ADE                   | Vs no vit. ADE given | 0.25 (0.07, 0.86)         |
| COW-VACCINATION           | Vs none given | —                        |
| EASE $\times$ COW-VACCINATION | Assist $\times$ vaccination | 15.28 (1.34, 173.61)     |
| SIRE$^b$                  | Various sires | —                        |
| NAVAL-TREAT               | Iodine     | —                        |
|                           | Chlorhexidine | Very small$^c$             |
|                           | Other      | +                        |
| EASE $\times$ NAVAL-TREAT | Assist $\times$ iodine | —                        |
|                           | Assist $\times$ chlorhexidine | Did not pass tolerance |
|                           | Assist $\times$ other | 0.11 (0.01, 0.90)         |
| HOW-COLOSTRUM$^b$         | Assist vs no assist | 12.41 (1.53, 100.89)     |
| EASE $\times$ HOW-COLOSTRUM | Assist $\times$ assisted feed | 0.08 (0.01, 0.71)       |

$^a$Odds ratio of dying in the time from birth to weaning, controlling for farm, month and year of birth. Only odds ratios significant at $P < 0.05$ are shown. Lemeshow and Hosmer's statistic, p-value = 0.838. A larger p-value indicates a better fit of the model to the data.

$^b$See text for details.

$^c$The odds ratio for chlorhexidine was 0.000031, with a 95% CL of (0.0000023, 0.000040), that is, calves whose navels were treated with chlorhexidine were at least 2500 times more likely to live (based on the upper limit of the 95% CL) than calves whose navels were not treated at all. They were at least 1800 times more likely to live than calves whose navels were treated with iodine.
TABLE III

Individual heifer calf management factors affecting whether or not calves died during the neonatal period (< 28 days) on Holstein dairy farms in southwestern Ontario, 1980-83

| Variable                      | Categories                      | OR^a (95% CL)          |
|-------------------------------|--------------------------------|------------------------|
| EASE^b                        | Assist vs no assist             | 47.98 (3.23, 713.17)   |
| HOW-COLOSTRUM                 | Assist vs no assist             | +                      |
| TIME^b                        | Day vs night                    | -                      |
| COW-ADE                       | Vs no vit. ADE given            | -                      |
| CALF-ANTIMICROBIAL            | Vs none given preventively      | -                      |
| HOW-COLOSTRUM × TIME          | Assisted feed × day             | 10.76 (1.05, 109.94)   |
| EASE × HOW-COLOSTRUM          | Assist × assisted feed          | -                      |
| COW-VACCINATION               | Vs none given                   | -                      |
| EASE × COW-VACCINATION        | Assist × vaccination            | +                      |
| BIRTHPLACE                    | Stanchion vs maternity pen      | +                      |
|                               | Freestall vs maternity pen      | +                      |
|                               | Pasture vs maternity pen        | -                      |
|                               | Corral vs maternity pen         | +                      |
|                               | Other vs maternity pen          | 25.70 (1.19, 556.43)   |
| EASE × TIME                   | Assist day                      | -                      |

^aOdds ratio of dying at < 28 days of age, controlling for farm, month and year of birth. Only odds ratios significant at P < 0.05 are shown. Lemeshow and Hosmer's statistic, p-value = 0.270. A larger p-value indicates a better fit of the model to the data.

^bSee text for details.

DISCUSSION

General considerations

The Lemeshow and Hosmer statistics indicated that the models considered were acceptable. Nevertheless, the winter mortality model at the farm level did not give as good a fit to the data as one would have wished (P < 0.07).

Increasing farm size has been reported to be associated both with increasing calf mortality (Speicher and Hepp, 1973; Hartman et al., 1974; Hird and Robinson, 1982), and with decreasing calf mortality (Jenney et al., 1981). These differences have been attributed to various factors, including housing factors, general management practices, and owner age and experience. A FARM SIZE effect, independent of other management factors (such as seen in this study), suggests that some other factors, perhaps related to crowding or contamination, have not been measured. Also, effects predicted by various herd immunity models could be expected to contribute to a farm size effect, namely, the larger the pool of susceptible animals, the longer potentially pathogenic organisms can perpetuate themselves and the more likely they are to spread (Yorke et al., 1979). Finally, the possibility that this effect is, at least in part, an artifact of the analytical methods used.
cannot be ruled out. Given a constant probability of dying, larger farms would have been more likely to experience some mortality, and hence would have been classified above the median.

Bowman et al. (1977) reported no difference in calf mortality on farms where calves had extra teats removed before first lactation versus those where they were removed later. The increased odds of experiencing above-median summer mortality on farms in this study that removed extra teats at four weeks to weaning (Table I) is consistent with similar patterns seen for calf morbidity (Waltner-Toews et al., 1986b). It is possible that farmers who waited until the calves were more than four weeks old to remove extra teats were simply neglectful managers. Combined with the manipulative stress itself, this neglectful management may have resulted in the higher calf mortality seen in the four-weeks-to-weaning group. Those farmers who removed teats early and those who removed them later (perhaps after selecting replacements?) would, according to this hypothesis, be better managers. This practice was not evaluated at an individual calf level and hence the above interpretation remains highly speculative.

**Associations of mortality with preventive treatments**

Various policies of administering preventive treatments to dams or calves (vitamins, anti-scour vaccines, antimicrobials) had no significant impact on whether or not farms experienced calf mortality. At an individual animal level, calves born from vitamin ADE-treated dams were less likely to die than calves whose dams were not treated (neonatal model \( P \leq 0.10 \); pre-weaning model \( P \leq 0.05 \)).

Calves from dams which had been vaccinated with an anti-scour vaccine experienced, in general, no difference in mortality from calves from unvaccinated dams. However, if calves from vaccinated dams required assistance at birth, they were far more likely to die than calves from unvaccinated dams which had assisted births (Table II). It cannot be determined from this data if this is a direct, biological effect of the vaccine on the fetus, or if sociopsychological factors, such as decreased vigilance of farmers toward calves of vaccinated dams, are involved. Some of these questions are addressed more completely in the context of a vaccine field trial which was carried out on these farms (Waltner-Toews et al., 1985).

Navel treatment of newborn calves has not previously been demonstrated to alter a calf's chances of survival. In this study, a farm policy of navel-treating newborn calves had no significant effect on calf mortality rates. Individual calves which required assistance at birth were less likely to die (than untreated calves) if their navels were treated (EASE × NAVEL-TREAT interaction, Table II). In general terms, however, only chlorhexidine had a significant — and beneficial — effect on calf survival. Other navel treatments, such as iodine, had no significant effect, but the general direction of their effect was to increase the odds of dying.
The only other preventive treatment which was demonstrated to affect calf survival in this study was the administration of a preventive antimicrobial to a healthy newborn calf (CALF-ANTIMICROBIAL). This tended to decrease the odds ($P \leq 0.10$) of a calf dying. The general pattern and impact of antimicrobial usage on these farms is discussed elsewhere (Waltner-Toews et al., 1986c).

**Associations of mortality with calving factors**

The effects of calving ease on calf mortality seen in this study (Tables II and III) are similar to those reported by other researchers (Laster and Gregory, 1973; Cady and Burnside, 1981). All forms of assistance at birth were associated with significantly increased odds of dying in this study. The odds ratios compared to unassisted births followed a predictable pattern: 3.6 for a hand pull, 5.9 for calf jack, 8.4 for abnormal presentation, and 46.5 for caesarians. Martinez et al. (1983) described a genetic effect on perinatal calf mortality which is attributable to the sire, but concluded that greater progress could be made if sire selection were based on calving ease characteristics rather than on perinatal calf mortality itself. The SIRE effect seen in this study supports the hypothesis that there is a genetic component, related to the sire, of calf livability, which is over and above the effect mediated through calving ease, and which extends beyond the immediate perinatal period. Testing of this hypothesis would require a very large data base, such as that available to artificial insemination, production recording, or breed organizations.

Usual patterns of BIRTHPLACE did not significantly alter the odds of experiencing calf mortality at the farm level. The significant effect of 'other' calving place on neonatal calf survival at the individual animal level (Table III) can best be explained in light of the fact that calves in this category were born in unusual and/or unexpected places on the farm, so that the circumstances of the birth (e.g. unattended calvings in unclean surroundings) were less than ideal.

The younger age at death for calves born in maternity pens may represent a baseline rate, related to congenital problems. One would expect such deaths to occur earlier than management-related deaths. The lower overall mortality rate for calves born in maternity pens versus all other indoor calving places is consistent with this hypothesis.

**Associations of mortality with colostrum feeding practices**

Method of first colostrum feeding per se has not been demonstrated, under experimental conditions, to significantly affect immunoglobulin absorption in newborn calves (Fallon, 1979). Certainly no effect on mortality has been reported. In this study, farms where farmers had a practice of routinely assisting calves to be suckled, or of supplementing the free-choice
suckle, had decreased odds of losing calves (winter mortality) compared with farms where newborn calves were routinely left to suckle on their own. At the individual calf level, however, supplemented or assisted first colostrum feeding was only beneficial to the calf if that calf had required assistance at birth. (This is relative to calves that were assisted at birth but were not supplemented/assisted to receive first colostrum.) ‘Naturally’ born calves that received assistance or supplementation in first colostrum feeding were more likely to die than calves left on their own. The beneficial effect of assisted feeding after assisted calving, and the beneficial effect of a general farm policy of assisted/supplemented first colostrum feeding, appear biologically plausible. It is possible that the general detrimental effect of supplemented/assisted first colostrum feeding at the individual calf level reflects a situation where calves which receive this assistance are already weak and physically compromised and therefore not only require assistance, but are also more likely to die than strong calves which do not require such assistance. Also, since it is not known whether or not assisted/supplemented calves were fed colostrum in the presence of the dam, a ‘dam effect’, as described by both Selman et al. (1971) and Stott et al. (1979), cannot be ruled out. If hand fed (supplemented) calves were usually removed from the presence of the dam for first colostrum feeding, or between feedings, then they might be expected to have achieved lower serum immunoglobulin levels than calves which were left to be suckled. The apparently contradictory results seen between the farm-level main effect of HOW-COLOSTRUM and the main effect at the individual calf level underlines the danger of assuming that findings from one level of analysis (farm level) are applicable to another (individual). This has been termed the ecologic fallacy (Susser, 1973), and is one of the pitfalls of observational studies in populations where the sampling and analytic unit is not the individual but an aggregate of individuals such as a farm. In this case, the sparing effect of assisted first colostrum feeding at the farm level reflects the effect of a policy of ensuring that all calves receive first colostrum. This is demonstrated by the fact that the calves which were not assisted (suckle only) on the ‘Assist Policy’ farms had a higher survival rate than the ‘suckle only’ calves born to farms where farmers were not so vigilant about first colostrum feeding (No Assist Policy). The interaction between EASE and HOW-COLOSTRUM, as well as the farm level/calf level effects, are displayed in Fig. 1.

Associations of mortality with calf housing practices

Previous field studies have reported increased mortality (Ferris and Thomas, 1975), no difference (Speicher and Hepp, 1973) or even decreased mortality (Staples and Haugse, 1974) associated with group penning of calves versus individual penning. Neither experiments nor observational studies have reported any effect of outdoor hutch housing on calf mortality,
Fig. 1. The effects of first colostrum feeding practices at farm and individual calf levels, for different calf birth experiences, on 35 southwestern Ontario Holstein dairy farms. At each node of the diagram, n = the number of calves in that category; the percentage calf mortality in that group of calves is given below that.

although Martin et al. (1975b) reported a trend in this direction in a field study in California.

In this study the association of increased odds of summer calf mortality with group penning of calves, and decreased odds with hutch rearing, was consistent with the nonsignificant patterns seen at the individual calf level, as well as with patterns of morbidity reported earlier (Waltner-Toews et al., 1986b). Climatic conditions of southwestern Ontario involve heavy snows and below-freezing temperatures for several months in the winter, as well as high humidity and near 30°C temperatures in the summer. It may therefore be important that the significant decrease in odds of mortality associated with outdoor hutch, and increase associated with group pens, was seen for the summer months only.

Associations of mortality with calf rearing personnel

Finally, several previous field studies have reported that dairy farms which used hired help to care for their calves had higher calf mortality
rates than farms where owners cared for them (Speicher and Hepp, 1973; Martin et al., 1975b; Ferris and Thomas, 1975; Jenney et al., 1981). At least two of these studies (Speicher and Hepp, Ferris and Thomas) suggested that farms where the farm-wife cared for the calves had lower mortality than where the farm-husband cared for the calves. While calf rearing personnel did not enter as a significant factor in the final models (i.e. including interaction terms) of mortality on these farms, this variable did appear as significant, for both summer and winter mortality rates, in models which included only main effects. During the summer, farms on which family members other than the owner cared for the calves had significantly greater odds of experiencing mortality than farms where the owner did this work himself (OR=2.8). Farms which used hired help did not differ significantly in odds from those where the owner cared for the calves.

In the case of winter mortality, farms which used hired help had significantly lower odds of experiencing mortality (OR=0.08) relative to farms where the owner cared for the calves. Farms on which the family members other than the owner reared the calves did not differ in their odds of mortality relative to farms on which owners reared the calves.

This study grouped all family members other than the owner (i.e., spouse, children, retired parents) into one category; it is possible that a shift from spouse-caretakers to (less careful?) children caretakers occurred from winter to summer. This might explain the different effects seen for the 'family members' category for winter and summer. The effects of using hired help, which differ from those found in earlier studies, may reflect the small numbers of farms which used hired help in this study group (only three per year), the relatively small size of even the largest farms on this study, or the particular characteristics of the people involved.

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