Mortality in Swedish Dairy Calves and Replacement Heifers

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ABSTRACT

The mortality of 8,964 heifer calves born in 122 dairy herds in southwest Sweden in 1998 to 2000 was monitored from January 1998 until December 2000. Farmers were requested to send carcasses for necropsy from animals that died from 1 d of age to first calving. Age and seasonal patterns of mortality were investigated using Kaplan-Meier curves. The median herd-level mortality risk was 2.1%. In total, 3.1% of the animals died before 90 d of age, 0.9% between d 91 and 210, and 2.2% between d 211 and first calving or d 810 (27 mo of age). The median age at death was 50 d and the risk of dying was highest during the first week of life. Of the 421 dead animals, 236 (56%) were subjected to either postmortem examination or were diagnosed as having died from trauma based on information from the farmers. In total, pneumonia was the most common cause of death (27%). However, in calves less than 31 d old, enteritis was the most common cause of death; in young stock 211 to 450 d old, trauma dominated; and in young stock more than 450 d old, trauma and calving-related diseases accounted for a majority of the mortality. The largest proportion of deaths was observed from January to March, and in June. Kaplan-Meier curves suggested that housing in small-group pens was associated with the lowest mortality (other housing systems were single pens and large-group pens with automatic milk feeders), but the association was not significant.

Key words: dairy calf, mortality, risk factors, death cause

INTRODUCTION

The mortality of dairy calves has been investigated by several authors and found to vary considerably between countries as well as between herds within a region. Low mortality risks were reported from Sweden and Norway (1.2 to 1.5% in the first month of life; Simensen, 1982; Olsson et al., 1993), whereas substantially higher levels

were reported from Denmark, France, and the United States (Wells et al., 1996; Fourichon et al., 1997; Nielsen et al., 2002).

Several risk factors for calf mortality have been identified, including group housing (Waltner-Toews et al., 1986; Olsson et al., 1993; Willard et al., 1996), indoor housing (vs. hutches), routine antibiotic treatment of calf diarrhea (Lance et al., 1992), slatted floor pens (Olsson et al., 1993), inadequate passive transfer of colostral immunoglobulin (Jenny et al., 1981; Wells et al., 1996; Tyler et al., 1999), being born to a first-lactation heifer (Olsson et al., 1993; Nielsen et al., 2002), being born at a difficult calving (Waltner-Toews et al., 1986; Wells et al., 1996; Nielsen et al., 2002), and being separated from the dam more than 24 h after birth (Jenny et al., 1981; Wells et al., 1996). Speicher and Hepp (1973), Lance et al. (1992), and Nielsen et al. (2002) reported increasing mortality with increasing herd size, whereas Jenny et al. (1981) found the opposite. James et al. (1984) found no association between mortality and herd size.

Less work has been conducted on the causes of calf mortality, and most of the studies reported producer diagnoses. Sivula et al. (1996) performed postmortem examinations on 52 calves and used necropsy results as the gold standard to evaluate the sensitivity and specificity of producer diagnosis of mortality; specificities were high: 93% for mortality due to enteritis and 100% for that due to pneumonia, but sensitivities were low: 58 and 56%, respectively. Articles presenting data from necropsies are especially sparse; Virtala et al. (1996) performed postmortem examinations of calves born in 1990 in 18 dairy herds in southwestern New York that had died before 90 d of age. Of the 21 calves examined, the majority (43%) had died from diarrhea, 24% from pneumonia, 10% from septicemia, and 24% from other single causes. Agerholm et al. (1993) made postmortem examinations of 110 animals aged 1 d to 6 mo from 65 Danish herds and reported that septicemia (28%) was the most common cause of death in calves 1 to 28 d of age. A further 21% of the calves of this age died from enteritis, and pneumonia was responsible for 12% of the mortality. Pneumonia was, however, the predominant cause of mortality in calves 1 to 6 mo old

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(46%), and the overall most common cause of death in calves 1 d to 6 mo old.

Knowledge of the causes of death and factors influencing mortality are of vital importance in identifying opportunities to improve the health status of calves. Calf mortality may also be of considerable economic importance to the dairy farmer. Calf management differs considerably between countries and results from one country may therefore not necessarily be relevant to dairy farms in another. Furthermore, the management of dairy calves has changed considerably during the past years. New housing systems are being used, which have not been considered in previous studies, and herd size increases steadily. The objectives of the present study were 4-fold: to make an updated estimate of the mortality risk, to identify its causes by using necropsies, to describe age and seasonal patterns, and to investigate effects of housing and herd size on mortality in Swedish medium-sized dairy herds.

MATERIALS AND METHODS

Selection of Herds and Animals

In 1997, a questionnaire about housing of replacement heifers and a request to farmers to participate in the study were sent to 485 dairy farmers in one county in southwest Sweden. All the farmers were enrolled in the official Swedish milk- and health-recording program (Olsson et al., 2001), had a herd size of 28 to 94 cows, and were deemed by their veterinary surgeons and farm advisors capable of keeping detailed records of the performance of their calves and replacement heifers. There were 355 responses by farmers (73% of the mailing list) to the questionnaire, and 136 of these farmers were willing to participate in the study, which included a statement that they intended to maintain their dairy production until at least 2005. All 122 herds that kept their young calves in individual or group pens and their replacement cattle in group pens with slatted floors, deep-litter boxes, or deep-bedded pack system boxes were included in the study. A statistical comparison (Svensson et al., 2003, 2006) of average annual herd-level milk production, and distribution of herd sizes, housing systems, and different feeding and management practices for calves and replacement heifers (such as use of calving pens, colostrum feeding routines, and feeding and breeding strategies) among these farms and a random sample of 877 Swedish dairy herds of similar size (Pettersson et al., 2001) revealed no significant differences. The study herds, therefore, can be considered a reasonably representative sample of Swedish dairy herds enrolled in the official milk-recording program, with a herd size of 28 to 94 cows and with individual pens or group pens as housing systems for

their young calves and litter pens or slatted floor pens for their older calves and replacement heifers. The study comprised all heifer calves born alive on the farms from January 1998 to December 2000, or until the herd was sold or, on a farmer's initiative, was withdrawn from the study, in total 8,964 animals. During the study period 2 herds were sold because the farmer had health problems, and 3 herds were sold mainly due to the impaired economic conditions for dairy farming in Sweden. Six herds were lost from the study because the farmer no longer wanted to participate as a result of death in the family or lack of time or interest. The births of calves were evenly distributed throughout the 3-yr period. The monitoring phase began on January 1, 1998, and ended on December 31, 2000 or, in case of a herd being sold or withdrawn during the study period, the day of sale or withdrawal. Animals were monitored from 1 d of age until first calving or, alternatively, the day they were removed from the study.

Data Collection

During the monitoring phase, farmers were requested to record all cases of mortality in their heifers on special forms, also gathering information about disease history and death dates of the deceased animal. Carcasses of all study animals that died or were euthanized because of severe illness were to be sent to necropsy. Animals that had died from trauma were, however, not considered for postmortem examination. Postmortem examinations were free of charge for the farmers in this study, but they were to transport the carcasses to the laboratory themselves or to call the project leader for transportation. Five times per year, project veterinarians, who checked and collected the mortality records, visited the farms. The farmers also received several postcards and letters encouraging them to send their dead animals for necropsy. Loss of carcasses to postmortem examination was mainly due to failure of the farmers to transport carcasses to the laboratory. The reasons for not sending carcasses for necropsy, according to the farmers, were most often lack of time or a long distance to the laboratory. The farms located farthest away were approximately 80 km from the laboratory. There was no reason to believe that diagnoses of cases not subjected to postmortem examinations would differ systematically from those of cases sent in.

At the time of farm visits, the project veterinarians also recorded individually for each calf the housing system used. Housing system was classified as "individual" pen if the calves were housed individually until at least 5 wk old. Group pens for 3 to 8 calves with manual feeding of the milk were classified as "small" and those

for 6 to 30 calves with automatic milk feeders were classified as "large." Calves in small group pens were transferred to these pens shortly after birth, whereas calves in large group pens were kept individually until 1 to 2 wk of age. Continuous stocking was used in the group housing systems. Information about birth dates and breeds of the calves, and the parity of the dam (heifer or cow) was obtained from the official milk- and health-recording program.

Necropsies were performed according to standard protocol at the laboratory of Lantmännen Analycen AB, Skara, Sweden. Samples were collected from all tissues with macroscopic pathological changes and were sent to the Swedish National Veterinary Institute, Uppsala, where they were prepared using routine laboratory procedures, stained with hematoxylin and eosin, and examined for histopathological lesions. Additional staining methods were used on indication. Bacteriological examinations were performed at Lantmännen Analycen AB, Lidköping, Sweden, using standard laboratory procedures (Carter and Cole, 1993). If an animal not subjected to postmortem examination had been examined by a practicing veterinarian and given a clear-cut diagnosis just before death or euthanization, this diagnosis was accepted as cause of death.

Editing of Data and Statistical Analysis

A variable representing season was constructed based on the birth dates of the calves. The period from May 1 to August 31 (when the cows and young stock are on pasture, only young calves are kept indoors, the weather is usually dry, and the calf premises most often are high-pressure cleaned) was defined as summer, September 1 to November 30 (when cows and young stock return from pasture and the weather is often humid) was defined as autumn, and December 1 to April 30 (when young stock and cows are kept indoors, calf premises most often have been used by a number of calves since previous high-pressure cleaning, and the weather may be cold) as winter.

An approximation of the probability for calves and replacement heifers aged 1 to 810 d to die due to enteritis, respiratory disease, trauma, and any cause, respectively, as well as during the 3 seasons was described by the Kaplan-Meier estimator, also called the Product-Limit method (PROC LIFETEST; SAS Institute, 1999–2001), disregarding the fact that there might be a dependence of herd. Kaplan-Meier curves describing the probability of dying between d 2 and 90 of life was similarly calculated for each season and housing system. Calf-level incidence risks were estimated using the Kaplan-Meier curves for total mortality. Incidence rates for calves 1 to 90 d, 91 to 210 d, and for 211 to

810 d of age were calculated using calf-month at risk within the age period of concern in the denominator; the total number of days contributing from each calf was divided by 30 to give the number of calf-months at risk. To describe the variation of death over the months of the year, the rate of death per day under risk was calculated for each month of the year. Only days when the animals were younger than 810 d were considered. This was done by dividing the number of deaths during the actual month by the total number of days at risk for the actual month. Herd-level incidence risks for calves 1 to 90 d of age was calculated, dividing the number of calves that died between 1 and 90 d of age by the total number of calves born in the herd during the study period.

Initially, an attempt was made to evaluate the effect of individual-calf-level and herd-level predictors using a 2-level (calf; herd) variance components logistic model, but this failed, most likely due to the unbalance in the data and the many predictors. Instead, the effect of housing on the risk of death at 1 to 90 d of age was evaluated using a GLM model for each season and a logit link function with breed, parity (separated into parity 1 or parity larger than 1), and housing in the model as explanatory variables. Only Swedish Red and Whites and Swedish Holsteins, calves of the 2 dominating breeds in Sweden, were considered in this analysis. Herd-level variation was accounted for by including an effect of herd in the model, as applied in the SAS PROC GLIMMIX (Littell et al., 1996). All first- and second-order interactions were tested, but none of them were significant at level $P < 0.05$. The effect of herd size on 1 to 90 d herd-level mortality was evaluated using the Spearman partial correlation with number of calf caretakers, percentage of calf management performed by female caretaker, the average annual herd-level milk production, percentage of calves being Swedish Holstein, and the most common housing system for calves as partialled variables (PROC CORR; SAS Institute, 1999–2001). Housing system was included as an ordinal variable (small group pen = 1, single pen = 2, and large group pen with automatic milk feeders = 3) based on information from the literature. The effect of most common housing system on 1 to 90 d herd-level mortality was analyzed similarly.

Descriptive statistics for the different causes of mortality was made using MS Excel 2003 for Windows. For analyses not specified above, MATLAB version 7.0.4 (Mathworks Inc., Natick, MA) was used.

RESULTS

In total, 3.1% of the calves died or were euthanized ($n = 36$) before 91 d of age. The mortality risk was 0.9%

Figure 1. Kaplan-Meier curve showing cumulative probability of dying at 1 to 810 d of age in 8,962 heifer calves and replacement heifers born from January 1998 to December 2000 in 122 dairy herds in southwest Sweden. A mortality probability of 0.031 at 90 d of age can be interpreted as 3.1% of the animals at risk having died at 90 d of age.

in calves 91 to 210 d old, and was 2.2% in older heifers, 211 to 810 d old. The cumulative probability of dying during the rearing period is shown in Figure 1. The mortality rate for calves 1 to 90 d of age was 0.009 deaths per calf-month at risk, 0.002 for calves 91 to 210 d of age, and 0.001 for young stock 211 to 810 d.

The mortality risk was low in most herds; 26% of the herds had no mortality and 47% had a mortality risk of less than 2% in calves 1 to 90 d of age. The highest mortality risk recorded was 18.6%. The median herd-level mortality risk for calves 1 to 90 d of age was 2.1% [50% central range (CR); i.e., excluding 25% of the values at each end of the distribution: 0.0 to 4.3%].

Of the 421 calves and young stock that died or were euthanized during the 3-yr study period, 236 (56%) were subjected to postmortem examination, were diagnosed as having died from trauma based on information from the owner ($n = 43$) or had been given a firm diagnosis by a practicing veterinarian just prior to death or euthanization ($n = 31$). The distribution of calves subjected to postmortem examination throughout the study period is shown in Figure 2. In total, pneumonia was the most common cause of mortality. However, enteritis was the dominating cause of death in calves less than 31 d old. In young stock 210 to 450 d old, trauma took most lives and in young stock more than 450 d, trauma and calving-related diseases were the main diagnoses (Table 1). Nine calves from 1 herd died in a train accident. Other types of trauma were fractures, dislocation, entrapment in the fittings, and drowning.

Pathogens isolated from the lung tissue of calves that died from pneumonia included *Pasteurella multocida*,

Figure 2. Distribution of calves and replacement heifers aged 1 to 810 d born in 122 dairy herds in southwest Sweden from January 1998 to December 2000 and examined postmortem, diagnosed as having died from trauma or given a clear-cut diagnosis by a veterinarian just before death or euthanization in relation to the total number of deceased animals.

Escherichia coli, *Arcanobacterium pyogenes*, *Mannheimia haemolytica*, α - and β -hemolytic streptococcae, and *Haemophilus somnus*. Pathogens isolated from diarrheic calves were mainly rotavirus, *E. coli*, and *Cryptosporidium parvum*. Isolates of *E. coli* were not further typed.

The risk of dying was highest during the first wk of life (Figure 1). The median age at death was 50 d (50% CR: 18 to 165 d). Calves that died from enteritis were 20 d (50% CR: 8 to 56 d) and those that died from pneumonia were in median 67 d (50% CR: 35 to 161 d). The probability of dying due to enteritis peaked during the second week of life (data not shown). The youngest calf that died due to pneumonia died at 8 d of age and deaths due to pneumonia were relatively evenly distributed throughout the following 3 mo of life.

Total mortality was highest from January to March, and in June, when a large proportion of deaths from enteritis and trauma were observed (Figure 3, panels a to d).

No significant associations were demonstrated between mortality in calves 1 to 90 d and housing and season, respectively. However, the Kaplan-Meier curves suggested that the risk of dying was lowest in calves housed in small group pens (Figure 4, panels a to c) and that the risk of mortality was higher for calves born during the winter months (Figure 5). Furthermore, there was a tendency for the herd-level mortality to be correlated with housing system (small group pen =

Table 1. Main diagnoses in 421 calves and young stock from 122 dairy herds in southwest Sweden that died between January 1998 and December 2000

Main diagnosis	Age at death					Total
	1 to 30 d	31 to 90 d	91 to 210 d	211 to 450 d	>450 d	
Pneumonia	12 (4) ¹	26 (3) ¹	15	9 (1) ¹	2	64 (8) ¹
Enteritis	23 (4) ¹	11 (3) ¹	3	2 (1) ¹	0	39 (8) ¹
Naval inflammation	7 (1) ²	3	1	0	0	11 (1) ²
Arthritis	4 (1) ²	3	0	0	0	7 (1) ²
Other infectious diseases	7	4	5	4	0	20
Bloat	2	3	0	2	1	8
Other digestive disorder	10	10	0	0	1	22
Malformations	4	4	3	0	0	11
Deficiency diseases	2	0	1	2	0	5
Trauma	8	5	4	17 ³	8	42
Other single causes	3	0	0	0	1	4
Calving related diseases	0	0	0	0	10	10
Mastitis	0	0	0	0	2	2
Cause of death not determined	77	47	33	21	7	185
Total ¹	154	113	65	57	32	421

¹Five calves died from simultaneous pneumonia and enteritis.

²One calf died from simultaneous arthritis and navel inflammation.

³Nine calves from one herd died in a train accident.

1, single pen = 2, large group pen with automatic milk feeders = 3; $r = -0.18$, $P = 0.05$).

There was also a tendency for the herd-level mortality to be correlated with herd size ($r = 0.18$; $P = 0.05$).

DISCUSSION

The estimated mortality risk was within the same range as previously reported from Sweden by Olsson et al. (1993). The disease contributing to the majority of the mortality in young calves was enteritis, which is in accordance with finding by Shoo et al. (1992), Virtala et al. (1996), and Sivula et al. (1996). Similarly to Agerholm et al. (1993), the present study found pneumonia to be the most common cause of mortality in calves aged 1 to 6 mo and also the overall most common cause of death, as was also reported by Figueroa et al. (1977) and Blom and Thyssen (1980), with both studies recording mortality of calves until 120 d of age. To our knowledge the present study is the first to report cause-specific mortality in young stock from 6 mo of age. Trauma and trauma together with calving-related diseases was the main cause of death in animals 211 to 450 d old and more than 450 d, respectively. Trauma constituted 47% of all cause-determined mortality between 211 and 450 d of age. This estimate may, however, be somewhat of an overestimation because 9 of the animals that died from trauma were involved in the same accident and were run over by a train while at pasture. Furthermore, in case of trauma the diagnosis was based on information from the farmers, whereas other diagnoses were based on findings at autopsy. Because only 56% of the 421 animals that died during the study period were

subjected to postmortem examination, these other conditions most likely were under-diagnosed relative to trauma.

The large number of calves that were lost for postmortem examination, in spite of the measures taken to encourage farmers to send in carcasses, illustrates the difficulties of carrying out studies of this type. Nevertheless, the 236 animals subjected to postmortem examination, diagnosed by the farmers to have died from trauma or having a clear-cut diagnosis by a practicing veterinarian just before death or euthanization makes this study, to our knowledge, the largest report examining mortality of calves and replacement heifers over 1 d of age.

The reasons for sale or withdrawal of herds were not related to calf health, and mortality of calves 1 to 90 d of age in these herds did not differ from those of the other herds (median: 1.5%; 50% CR: 0 to 5.1%). Hence, these losses most likely did not affect the results of the study.

Because death due to enteritis and pneumonia was determined at postmortem examination, it cannot be excluded that the seasonal and age patterns reported here for these causes of death was affected by the farmers' willingness to send in the carcasses of their calves to the laboratory. However, as shown in Figure 2, the distribution of carcasses with a determined death cause corresponded well to the distribution of deceased animals, although the cause of death was determined for a somewhat higher proportion of the animals that died during May to July compared with those that died during the rest of the year.

Figure 3. Rate of A) total mortality with and without 9 calves that died in a train accident in June; and B) mortality due to enteritis; C) pneumonia; and D) trauma with and without 9 calves that died in a train accident in June during different months of the year in 8,962 calves 1 to 810 d of age born in 122 dairy herds in southwest Sweden from January 1998 to December 2000, calculated as the number of deaths during the month in question divided by the total number of days at risk for that month.

We found the highest probability of mortality to occur during the first 3 wk of life, which is in accordance with findings from New York State and the United States (Curtis et al., 1988a; Wells et al., 1996). Sivula et al. (1996) investigated calf mortality in 30 dairy farms in southeast Minnesota and reported that the risk of death was highest at 2 wk of age.

The Kaplan-Meier curves suggested that calves housed in small-group pens for 3 to 8 calves with manual feeding of the milk might have a lower total mortality during their first 3 mo of life than calves in single pens or large-group pens for 6 to 30 calves with automatic milk feeders. The differences seemed to be most evident during the second and third months of life. Because calves in large group pens were kept in single pens during their first day of life, these housing systems did not differ until after 1 to 2 wk of age. Olsson et al. (1993) found that farms that kept their calves in group pens had higher mortality than those that kept them

individually. Waltner-Toews et al. (1986) reported that a similar effect was evident in summer. Materials and methods of these studies did, however, not reveal the size of the groups. Willard et al. (1996) investigated the effect of group size on mortality and found groups of 7 or more calves to be associated with increased odds compared with groups of 2 to 6 calves and calves not grouped, respectively. The lowest odds were found in calves kept in groups of 2 to 6 calves. The 2 group-housing systems in the present study not only kept different group sizes, but also involved different feeding systems (manual bucket feeding vs. automatic milk feeders). Although all calves within the large-group pens may have direct contact with other calves it cannot be excluded that the automatic milk feeder may serve as an additional transmitter of (mainly) respiratory diseases. Health data from calves born in our study herds in 1998 did not reveal a lower incidence of disease in the calves housed in small-group pens (Svensson et al.,

Figure 4. Kaplan-Meier curve showing cumulative probability of dying in relation to housing system if born during A) summer; B) autumn; and C) winter in 8,962 heifer calves 1 to 90 d of age born in 122 dairy herds in southwest Sweden from January 1998 to December 2000.

Figure 5. Kaplan-Meier curve showing cumulative probability of dying at 1 to 810 d of age in 8,962 heifer calves and replacement heifers born in 122 dairy herds in southwest Sweden from January 1998 to December 2000 with respect to season of birth.

2003), and from d 91 to 210 their risk of respiratory disease was, in fact, increased compared with calves that had been kept individually before weaning (Svensson et al., 2006). However, calves kept in small-group pens did have a higher growth rate than calves housed in single pens (Lundborg et al., 2003). Calves housed in small groups have been found to spend a longer time eating concentrates and roughage than single-housed calves (Dybkaer, 1988; Babu et al., 2004); stimulation by each other to consume solid feed has been suggested as an explanation for their higher growth rate (Warnick et al., 1977). It is possible that the higher feed consumption improved the ability of these calves to cope with diseases, so resulting in fewer deaths. The result may also reflect better welfare in small groups, where calves can have full social interaction and greater access to space than in single pens and where the level of competition has been found to be lower than in large groups (Jensen, 2004).

The Kaplan-Meier curves indicated that mortality was increased in calves born during winter, which is in accordance with previous results by Speicher and Hepp (1973). Data also suggested a high mortality rate in June, coinciding with a higher mortality rate due to trauma and enteritis. The high mortality rate due to enteritis in the summer supports the finding by Svensson et al. (2003) that summer was associated with an increased risk of severe enteritis. Curtis et al. (1988b) could not detect any effect of season on mortality while studying 1,171 calves 0 to 90 d of age from 26 New York Holstein herds.

The literature is to some extent contradictory concerning the effect of herd size on mortality. One expla-

nation for this may be that the studies have investigated different levels of herd size. Furthermore, Jenny et al. (1981) suggested that confounding with rolling average milk production might have contributed to their finding that increased herd size was associated with decreased mortality, and also in some of the other early studies confounding factors were not controlled for. In the present study, investigating smaller herds than most other studies, breed, housing system, average annual herd-level milk production and the number and sex of calf caretakers were adjusted for. Our borderline significant results further substantiate the opinion put forward in most studies investigating this matter, that increasing herd size indeed is a risk factor for calf mortality. Because herd size now increases rapidly in dairy production worldwide, studies to further elucidate the background of this association are urgently needed.

CONCLUSIONS

Our results confirm that the mortality risk of Swedish dairy calves is relatively low in an international perspective, while pneumonia is the most important cause of death in calves and enteritis contributes to mortality primarily in young calves. Furthermore, our study identifies trauma and calving-related diseases as the main causes of mortality in young stock more than 7 mo old, and provides additional indications that mortality increases with herd size.

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