Beef Sessions:

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Risk Factors Associated With Fatal Fibrinous Pneumonia (Shipping Fever) in Feedlot Calves

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Introduction

Fibrinous pneumonia (shipping fever) can be a major cause of death in feedlots, especially those where large numbers of recently weaned calves are purchased from auction markets in the fall.[1] Epidemiological studies show that the disease develops quickly after calves arrive at the feedlot; our previous work has shown that fully 75% of the calves that died of fibrinous pneumonia were sick within two weeks of arrival.[1] Studies of the biological, environmental, and population factors that are present before and shortly after arrival of calves at the feedlot are needed to identify strategies for reducing the incidence of fatal fibrinous pneumonia.

Fatal fibrinous pneumonia (FFP) does not affect calves in a random fashion across a beef feedlot. Instead, shipping fever mortality can be abnormally high (and therefore the disease can be said to cluster) in certain truckloads or pens of calves.[2] Knowing that FFP clusters within truckloads or pens of calves is important for two reasons. First, we can look for ways of predicting which truckloads or which pens of calves are at highest risk to the disease so that feedlot owners can observe them carefully and treat them aggressively upon their arrival at the feedlot. Second, the process of trying to predict where the disease will cluster might provide some important insights into the debate concerning whether shipping fever acts as a truly contagious disease. The latter is important in helping feedlot owners determine whether management procedures designed to prevent or contain a contagious disease are indicated.

Previous work employing primarily descriptive epidemiological techniques and stratified analyses has shown that a number of risk factors are associated with FFP. These risk factors include the population density of calves present at the auction markets where calves are purchased by a feedlot,[3] the time of year that calves are placed in the feedlot,[3,4,5] and the amount of mixing of calves from different farms that occurs at the auction market to complete a truckload for shipment to the feedlot.[6] Weather conditions that are prevalent around the time that calves arrive at the feedlot are also thought to contribute to the seasonal fluctuations in FFP risk, but a rigorous analysis of the importance of weather has not been done.[3]

In this paper we pursue the development of a technique to predict which truckloads or pens of calves are at highest risk to FFP by building a series of multivariate models in which we incorporated some of the above mentioned risk factors measured at a feedlot over a period of three years. These predictive models were then used to examine the question of whether FFP acts as a truly contagious disease in the feedlot. If multivariate models containing only non-contaagious factors could accurately predict where FFP would cluster, then perhaps only non-contagious factors work on particular feedlot pens or transport trucks to place calves in those groups at increased risk of developing FFP. If, however, models containing exclusively non-contagious factors were not effective at predicting where the disease clusters, this could mean that a "contagious factor" was missing from our models.

Materials and methods

Data

The subjects of this study were all 58,885 spring-born calves entering a large feedlot in SW Alberta between 1 September and 31 December for each of the years 1985 to 1988 inclusive. Most of the calves represented recently weaned calves that were purchased from auction markets. Further details of how and where the calves were purchased, how they were processed upon arrival at the feedlot, how they were diagnosed and treated for illness, and how the mortality data were collected and tabulated have been described previously.[2,7] Weather data were collected from the nearby Calgary weather office (Environment Canada). Weather parameters monitored were daily temperature (maximum and minimum), daily precipitation (rainfall and snowfall), daily hours of sunlight, maximum windspeed, and humidity.

The number of calves passing through western auction markets on a weekly basis was estimated using the weekly publication entitled the "Canada Livestock and Meat Trade Report" (Red Meats Division, Market Information Service, Agriculture Canada, Ottawa, Ontario, Canada, Volumes 66-69). The number of calves from different farms that were combined at the auction market to make up a truckload for shipment to the feedlot was determined by examining the sellers' names on the individual auction market tickets accompanying each truckload.[6] Truck manifests, dates of arrival, and feedlot processing records were used to link specific transport trucks to feedlot pens.[7]

Analyses

Analyses were performed separately on each of three years (1985-1987) of data. No analysis was performed on the 1988 dataset because FFP was found not to cluster that year within either trucks or pens.[2] Only those variables shown to be important in the descriptive and stratified analyses previously carried out were used in the modelling procedures.[3,6,7] Therefore, distance from the auction market to the feedlot, which was shown not to be associated with FFP in an earlier analysis,[7] was not included in the models. Weather variables were created to reflect a measure of inclement weather as experienced by incoming calves from the day of their transport to the feedlot until three days after processing (Table 1).

All variables were entered into full models in a microcomputer software statistics package (PC-SAS, SAS Institute, Cary, NC), then removed manually in a backward stepwise manner until only those variables (parameters) whose t test values (equivalent to the partial F statistic) were significant at the 0.10 level remained in the models.[8] Residual plots were examined to check

Table 1. Variables entered into truck-level models for mortality associated with fibrinous pneumonia.

Variable Name	Description
Precipitation	Total precipitation (cm) over four days beginning with the day prior to processing (ie. day of transport from market to feedlot)
Hrs of sunlight	Total sunlight (hrs) over four days beginning with the day prior to processing
Max temperature	Maximum temperature (°C) during four days beginning with the day prior to processing
Max temp drop	Maximum drop in temperature (°C) over four days beginning with the day prior to processing until three days after processing
Calves per farm	Mean number of calves contributed by single farms to a truckload
Time	Three dummy variables created for the months of Oct, Nov, Dec; Sep was the referent month
Buyer	Seven dummy variables created to represent eight buyers, with buyer 1 as the referent
Auction flow	Number of calves passing through nine auction markets in western Canada on a weekly basis from August until January
Sex	Heifer versus steer/bull calves

that no assumptions were violated by any of the final models; Cook's D statistic was used to check for influential observations.[8]

In 1985, cases of FFP clustered within truck, so we created statistical models that attempted to predict which truckloads of calves would be more likely to have serious problems with FFP. The truck-level variables entered into the models are listed and described in Table 1. The statistical details of how we performed linear regression on the logit of fibrinous pneumonia mortality occurring within individual truckload-groups of calves, and how we adjusted for clustering or "overdispersion" are recorded elsewhere.[9]

In 1986, FFP clustered within pen, so we created models to predict which pens of calves would be more likely to have serious FFP problems. Only three variables were used this time, those being Time, Auction flow, and Sex. The Time variable was further divided from months into two week periods for this analysis.

In 1987, cases of FFP clustered within both truckload and pen groups. As a result, two analyses were run, one attempting to predict FFP occurrence in truckloads of calves, another in pens of calves. To examine truckloads, we used the same variables as for the 1985 analysis (Table 1). To examine pen groups, we used a model similar to that created for 1986, including the same variables, with an additional step required to correct for the clustering that occurred within trucks in 1987.[9]

Results

There were mortality, buyer, and auction flow data on a total of 129 trucks in 1985. Unfortunately, the auction market tickets for 52 of these trucks were missing, so data concerning the number of farms contributing to each truckload were available for only 77 trucks. It was difficult to choose between two of the models for the 1985 analysis, because of similar performance, so both are presented as "final" models (Table 2). "Calves per farm" did not remain in either of the final models. Buyer 4 and the number of calves passing through the auction markets (auction flow) remained in both models, although in model 1 the auction flow was two weeks prior to the processing date (arrival at the feedlot) of a truck, while in model 2 the auction flow was three weeks prior to processing.

Two final models are presented for the pen-level analysis for 1986, one containing two time variables (early November and late November), the other containing "auction flow" one week prior to processing (Table 3). Time variables would not remain in the same model as the flow variable indicating that time and flow were correlated.

The final truck-level model for 1987 contained two weather variables, one variable for the degree of pre-transit mixing, one for time, and one for "auction flow" (Table 4). The one model that resulted from the pen-level analysis for 1987 contained one time variable and the "auction flow" four weeks prior to processing (Table 5).

The coefficients of determination for the 1985 and 1986 models were poor, varying between 22% and 27%. This means that the models "explained" only about one-quarter of the total variation among trucks or pens in FFP mortality. The 1987 model for pens had the highest coefficient of determination (58%).

Discussion

All of the variables that were found to be associated with FFP in our earlier descriptive work were found in one or more of the final multivariate models,[1,3,6] with the addition of two weather variables. The statistical model reported for truckloads of calves in 1987 (Table 4), for example, supported the hypotheses that FFP mortality was associated with the number of calves per farm on a truckload (a measure of the amount of pre-transit mixing at the auction market), time (November versus other months), and the population density of calves at the auction markets several weeks previous to arrival of a truckload at the feedlot ("auction flow").

Table 2. Statistical models[a] of factors associated with fibrinous pneumonia mortality occurring in 129 truckloads of calves entering a large commercial feedlot in SW Alberta during the fall months of 1985[b].

Variable[c]	Coefficient	Std. error of coefficient	p-value
Model 1			
Intercept	-4.141	0.211	<0.001
Buyer 4[d]	0.776	0.196	<0.001
Auction flow (2)[e]	0.005	0.001	<0.001
Model 2			
Intercept	-4.129	0.319	<0.001
Time2 (October)	0.409	0.231	0.080
Time3 (November)	0.752	0.337	0.028
Buyer 4[d]	0.771	0.216	<0.001
Auction flow (3)[e]	0.003	0.002	0.127

a: Two models presented because the model containing two time variables performed almost as well as the simpler model
b: Coefficient of determination for model 1 $R^2 = 0.22$, and for model 2 $R^2 = 0.21$.
Intraclass correlation coefficient value of 0.026 used in correction factor for variance calculation.
c: For a complete description of the variables, see Table 1.
d: Buyer 4 purchased calves exclusively from the Edmonton Public Stockyards in Edmonton, Alberta.
e: Refers to the estimated number of calves passing through nine western auction markets two (2) or three (3) weeks prior to the processing date for that truck.

Table 3. Statistical models[a] of factors associated with fibrinous pneumonia mortality occurring in 51 pens of calves in a large commercial feedlot in SW Alberta during the year 1986[b].

Variable[c]	Coefficient	Std. error of coefficient	p-value
Model 1			
Intercept	-4.484	0.128	<0.001
Time5 (early Nov)[d]	0.729	0.181	<0.001
Time6 (late Nov)[d]	0.632	0.262	0.020
Model 2			
Intercept	-4.862	0.447	<0.001
Auction flow (1)[e]	0.005	0.002	<0.025

a: One model containing both variables, time and auction flow, could not be created because of high correlation between the two variables.
b: Coefficient of determination for model 1 was R2 = 0.27, and for model 2 was R2 = 0.22.
c: For a complete description of the variables, see Table 1. The time variable was further split into two week intervals for this analysis.
d: First two weeks (Time5) and last two weeks (Time6) of November versus the months of September, October, and December combined.
e: Refers to the estimated number of calves passing through nine western auction markets one (1) week prior to the processing date for that truck.

Table 4. Statistical model of factors associated with fibrinous pneumonia mortality occurring on 152 truckloads of calves entering a large commercial feedlot in SW Alberta during the fall months of 1987[a].

Variable[b]	Coefficient	Std. error of coefficient	p-value
Intercept	-4.477	0.475	<0.001
Hours of sunlight	-0.016	0.008	0.058
Max temp drop (°C)	0.044	0.019	0.018
Calves per farm	-0.024	0.010	0.014
Time (November)[c]	0.447	0.137	0.001
Auction flow (4)[d]	0.004	0.001	<0.001

a: Coefficient of determination for the model was $R^2 = 0.36$. An intraclass correlation coefficient value of 0.015 was used in the correction factor for the variance calculation.
b: For a complete description of the variables, see Table 1.
c: Month of November versus the months of September, October, and December combined.
d: Refers to the estimated number of calves passing through nine western auction markets four (4) weeks prior to the processing date for that truck.

Table 5. Statistical model of factors associated with fibrinous pneumonia mortality occurring in 43 pens of calves in a large commercial feedlot in SW Alberta during the year 1987[a].

Variable[b]	Coefficient	Std. error of coefficient	p-value
Intercept	-4.862	0.447	<0.001
Time (November)[c]	0.704	0.234	<0.005
Auction flow (4)[d]	0.005	0.002	<0.025

a: Coefficient of determination for the model was $R^2 = 0.58$. An intraclass correlation coefficient value of 0.015 was used in the correction factor (CF = 1.753) for the standard errors.
b: For a complete description of the variables, see Table 1.
c: Month of November versus the months of September, October, and December combined.
d: Refers to the estimated number of calves passing through nine western auction markets four (4) weeks prior to the processing date for that truck.

The variable "calves per farm" remained in the final 1987 truckload model but not in the 1985 models. This was likely due to the reduced statistical power of the 1985 analysis that resulted from a large proportion of missing values for the number of "calves per farm" on 1985 trucks. However, the "Buyer 4" variable that remained in both 1985 models was probably a proxy or substitute variable for mixing. Calves in truckloads purchased at the stockyards in Edmonton by "Buyer 4" were subjected to more pre-transit mixing than calves in truckloads purchased by other buyers.[6] The multivariate models from both years, then, suggest that the number of individual auction market tickets accompanying an incoming truckload of feeder calves might be useful as an indicator of the problems with FFP that will be encountered in that truckload, compared to other truckloads arriving during a similar time period.

The finding that decreases in ambient temperature around the time of arrival at the feedlot were associated with increased FFP risk is consistent with the finding of MacVean *et al.*[10] that increases in the range of daily temperature were associated with increases in the incidence of treatment for pneumonia. Alexander et al.[11] also found that changes in temperature were associated with pneumonia morbidity, but the relationship was reversed. This difference was attributed by Alexander *et al.* to their potentially less precise method of measuring ambient temperature.

The variable "precipitation" did not remain in the final models. Precipitation is likely a poor measure of inclement weather in a geographic region where both rain and snow might be expected. To determine total precipitation after a snowfall the snow is melted and the resulting water column measured. From the perspective of a calf in the feedlot, the same measured precipitation represents a much longer period of inclement weather for a snowfall compared to a rainfall. Using the volume of water as a measure of the elapsed time of inclement weather may not, therefore, be a very useful estimate of the effects of the macroclimate on disease in conditions similar to these.

"Time" remained in most of the models. We originally thought that the time variable, in the form of November compared to other months, was really a proxy or substitute variable for both inclement weather conditions and calf density at the auction markets. However, "time" remained in most of the models along with variables for both weather and auction flow. This indicates that either our weather and auction flow variables were not very good measures of changes in weather and calf population density at the auction markets, or that there were other factors specific to November which affected the incidence of FFP.

One of the possible November factors we observed was a so-called "hospital effect". The consistent yearly pattern of calf purchases at the auction market and subsequent sickness at the feedlot ensured that November was the month during which there was maximum exposure of new "acute" cases of shipping fever in recently arrived calves to "old" cases of respiratory disease in calves that had been established at the feedlot for some time. Much mixing of these two disparate groups occurred in the hospital pens because the study was carried out at a time (1985-87) when shorter acting antibiotics were used for treatment and calves had to be held in a hospital pen for several days for their daily injections. We suspect that the reduction in mixing of calves in a hospital area which has resulted from the more recent practice of treating calves with longer acting antibiotics and immediately returning them to their home pens has reduced the risk of FFP in feedlots in the 1990's.

The variable "auction flow", adjusted by various lag times, remained at a highly significant level in all but one of the multivariate models. This indicates that FFP risk, at both the truck and pen level (depending on the year), was correlated with the number of calves passing through the auction markets a number of weeks prior to the entry of a truckload into the feedlot. Perhaps there was some kind of "residual effect" on calf health from the changing flow of calves that occurred at the auction market, at the feedlot, or both. Possible causes of this "residual effect" from the auction market include increased waiting times for transport trucks at the markets during peak periods, increased number of potential contacts between calves from different sources, increased stress due to "crowding", and reduction in the time available for the observation of individual calves at the feedlot as the feedlot approached capacity.[3]

The low coefficients of determination observed for all of the statistical models (with the exception of the 1987 pen model) indicated that although some variables that played an important role in the pathogenesis of FFP were identified, the models were not useful for predicting with precision which trucks or pens would become problems.[12] Too much of the total variation in FFP mortality among trucks and among pens was left unexplained. As a result, the interpretation of the models should be limited to noting the presence or absence of particular variables in the final models, and examining the signs (positive or negative) of their individual coefficients.

Only a few studies examining pneumonia in the feedlot have used multiple regression techniques and not one has reported a coefficient of determination of greater than 0.50 for any of the models produced. Martin *et al.* used stepwise multiple regression in their report from the third year of the Bruce County Beef Project to identify factors that might have influenced mortality, but they did not report any coefficients of determination for their models.[13] Multiple regression models reported by MacVean *et al.* for pneumonia morbidity at a feedlot in Colorado in 1982 and 1983 had coefficients of determination of 0.31 and 0.12 respectively.[10] Work carried out by Alexander *et al.* at the same Colorado feedlot in 1985 produced six multiple regression models for pneumonia morbidity with coefficients of determination varying from 0.11 to 0.49.[11] There is a strong potential for bias in all of these models, reducing confidence in the precision of the individual values for the estimated coefficients of the independent variables. Either some important variables were missing from the models, or the modelling technique itself was not entirely suitable for this complex biological system.

The relatively unrefined nature of the dependent variable (FFP) may have contributed to the poor predictive performance of the statistical models. Fatal fibrinous pneumonia is the endstage of a disease process. There may be several reasonably prevalent biological pathways that lead to the endstage of death "due to" fibrinous pneumonia. Considering a number of disease processes as one single disease will certainly hinder attempts to develop a clear causal picture. To reduce this problem improved diagnostic techniques are needed so that fibrinous pneumonia morbidity, as opposed to mortality, can be reliably diagnosed in the feedlot. This will require an ongoing collaboration between epidemiologists, molecular biologists, and specialists from a number of other disciplines including pathology, immunology, virology, and bacteriology.

The predictive value of the models could also be improved by further refinement of the independent or predictor variables used in the models. For example, the two measures of climate that were associated significantly with increased FFP (maximum temperature drop and hours of sunlight) were relatively unrefined macroclimatological measures.[14] Future studies designed to measure the specific microclimate within the three "climatological sheaths"[14] of the auction market pen, the transport truck, and the feedlot pen might markedly improve our estimate of the importance of climate as it relates to disease.

Unfortunately, our findings did not function as a "crucial test"[15] for the hypothesis that the principle agents of FFP act as a contagion. However, they have clearly failed to rule out this possibility. If FFP mortality was found not to cluster within truckloads of calves, or if the disease had clustered there but the statistical models were able to predict where the clustering occurred, there would have been strong evidence that the disease was not contagious on the truck. However, the disease did cluster,[2] and the models did not explain much of the truck to truck variation in disease. We can only conclude from the evidence presented that FFP mortality may be a contagious disease, but further work is necessary to eliminate alternative explanations for the clustering that was observed.

Perhaps the most important contribution of our study has been to emphasize that FFP is the veterinary equivalent of a "public health problem". There is a tendency, when standing in the feedlot and viewing clinical cases of shipping fever, to become too focussed upon the individual. Our findings suggest that, to gain a better understanding of the disease so that logical approaches to prevention and control can be developed, attention must be directed towards not just groups of calves, like truckloads or pens, but towards the entire feedlot. Attention directed towards the dynamics of using a hospital facility is an example of this. Indeed, if population dynamics at both the feedlot and at the auction market are important, if contagion is likely, and if changes in macro- and microclimate are significant, then broadening our research focus to entire populations of calves within large geographic regions (eg. the entire western Canadian herd) is appropriate.

Pasture conditions and climatological events during the summer, for example, may have a far greater effect on calf health at the feedlot than differences in mixing between different buyers at the markets. It may be that much of the increased incidence in FFP documented for 1987 in the present study1 was due to dry conditions on pastures in western Canada, resulting in early weaning of calves in comparatively poor condition. Studies designed to monitor FFP risk for a period of years (or even decades) at several large feedlots are needed to test such a "public health" hypothesis. Developing the political and structural framework necessary for the disease to be effectively examined in this way represents the next important step in shipping fever research.

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