Hierarchical model of pneumonic lesions in lambs at slaughter and investigation of spatial patterns of pneumonia prevalence

K.A. Goodwin[1], M. Stevenson[1], C.Heuer[1]
[1]EpiCentre, Private Bag 11222, Massey University, Palmerston North, New Zealand.

Abstract

Chronic non-progressive pneumonia is a common sub-clinical disease of lambs leading to production loss through reduction in growth rate and an increased predisposition to pleurisy. This was a prospective longitudinal observational study of pneumonia in 1.9 million lambs at commercial slaughter plants in New Zealand. A logistic regression model was used to quantify the effect of month, mob, flock and plant on the risk of pneumonia. The hierarchical structure of this data set accounted for mob and farm as nested random effects. Odds ratios of pneumonia in slaughter lambs of two North Island plants were 0.24 (95% CI 0.21, 0.29) and 0.70 (95% CI = 0.61, 0.81) relative to one South Island plant. Compared to December, the odds of pneumonia were highest for lambs slaughtered in March, April and May. Case farms were defined as those with an incidence risk of pneumonia greater than 80 cases per 100 slaughtered lambs. A spatial incidence risk surface was calculated as the ratio of density of case farms to density of the farm population at risk. A significant spatial cluster of moderate to severe pneumonia prevalence was identified in the South Island group of farms, but not in the North Island farms. Binned directional variograms (using standardised residuals of the logistic regression analysis) showed that after adjusting for farm-level effects there was no evidence of unaccounted-for spatial variation in pneumonia risk. We conclude that in this population farm management factors are more influential in determining pneumonia risk than geographical location.

Introduction

Chronic non-progressive pneumonia (CNP) is a common sub-clinical disease of lambs which leads to substantial production loss through reduced growth rates, a predisposition to pleurisy and reduced carcass value. The only accurate diagnosis for CNP in lambs is post-mortem examination of lungs at slaughter, however, it is not routinely recorded at processing plants as there is no direct effect on the value of the lamb carcass. Although broad-scale, regional differences in CNP prevalence have been identified (Black, 1997, Goodwin et al., 2004), variations in flock-level disease risk at finer spatial scales are largely unknown. The objectives of this study were to: (1) evaluate the ability of meat inspectors to classify pneumonic lesions; (2) quantify the influence of processing plant and month on the pneumonia prevalence of flocks; and (3) investigate the data for any residual, spatially correlated risk of pneumonia, after controlling for flock-level risks for disease.

Materials and methods

For each lamb processed between 1 December 2000 and 30 September 2001, lungs were visually assessed by meat inspectors and classified into categories as follows: no pneumonia, minor pneumonia (< 10% total lung surface area affected) and moderate to severe pneumonia (• 10% total lung surface area affected). The sensitivity and specificity of diagnosis was evaluated for each plant, allowing the true prevalence of pneumonia to be calculated.

Part I: Details of date, number of lambs slaughtered, number of lambs with each of the defined pneumonia scores and pneumonia prevalence were collated for slaughter lines of lambs.

Part II: A binomial multilevel logistic regression model was used where the proportion of lambs with moderate to severe pneumonia per mob (grouped by flock) was the outcome variable.

Explanatory variables included region (Canterbury, Manawatu, Gisborne), month of slaughter (January to September) and mob and flock identifier. The Markov chain Monte Carlo sampler in MLwiN version 2.01 (Rasbash et al., 2004) was run for 1 million iterations after discarding the first 100,000 'burn in' samples.

Part III: The study population was divided into case (high prevalence of pneumonia) and control flocks (low prevalence of pneumonia). The data set included flocks supplying • 30 lambs and located within a 50 km radius of each processing plant (Canterbury n = 292, Manawatu n = 271 and Gisborne n = 261). Case flocks were those in the 80^{th} percentile of moderate to severe pneumonia prevalence per region. Centroid coordinates of farm blocks were used. The spatial scan statistic implemented in SaTScan Version 4.0.3 (Kulldorff, 2003) was used to assess the presence of spatial clusters of case flocks per region. Standardised diagnostic residuals from the multi-level model were calculated and covariance in the residual values as a function of distance was assessed using directional variograms (Isaacs and Srivistava, 1989). Spatial dependence was deemed to be present given a relationship between distance and semivariance, and if some or all of the empirical variograms lay beyond the bounds of the upper and lower simulation envelopes.

Results

Part I: Meat inspector sensitivity was low and specificity was high for pneumonia diagnosis. Canterbury had the highest mean total pneumonia prevalence. The prevalence of pneumonia peaked earlier in Gisborne (March) compared with Canterbury and Manawatu (May).

Part II: Gisborne had the least moderate to severe pneumonia (OR = 0.3, 95% CI = 0.3, 0.4) compared with Manawatu (OR = 0.7, 95% CI = 0.6, 0.9) in comparison to the reference group, Canterbury. The odds of moderate to severe pneumonia from March to May were 11.0 - 13.7 times that of the reference month, December.

Part III: Results from the SaTScan analysis indicated a significant cluster of case flocks present in Canterbury (n = 5, p = 0.025) but not in the other two regions. Binned directional variograms (Figure 1) show that once the flock-level explanatory variables had been accounted for there was no residual spatial autocorrelation in any region, indicated by the lack of relationship between semivariance and distance, and each empirical variogram located well within the boundaries of the permutation-based envelopes.

Discussion

Analyses from an extensive database of lamb pneumonia levels recorded by meat inspectors at slaughter in three New Zealand regions have been presented. Validation of diagnosis showed sensitivity to be low and specificity high, therefore, the true pneumonia prevalence of the population was under-estimated. Multi-level analysis of the data, showed significantly lower odds of moderate to severe pneumonia in Manawatu and Gisborne lambs than Canterbury lambs and significantly higher odds of lamb pneumonia from March to May compared with December. A significant cluster of case flocks was found in the Canterbury region based on raw data, but no spatial patterns were evident in any region after adjusting for the fixed (processing plant, month) and random effects (clustering at mob and flock level) of the multilevel model. A limitation of these spatial analyses is that farm centroid co-ordinates were used as location indicators for flocks. The distance between farm centroids, therefore, is dependant on farm size.

Conclusion

In conclusion, factors operating at the flock level, within the control of farm managers, have a more importance influence on lamb pneumonia prevalence than environmental effects (e.g. climate and geography).

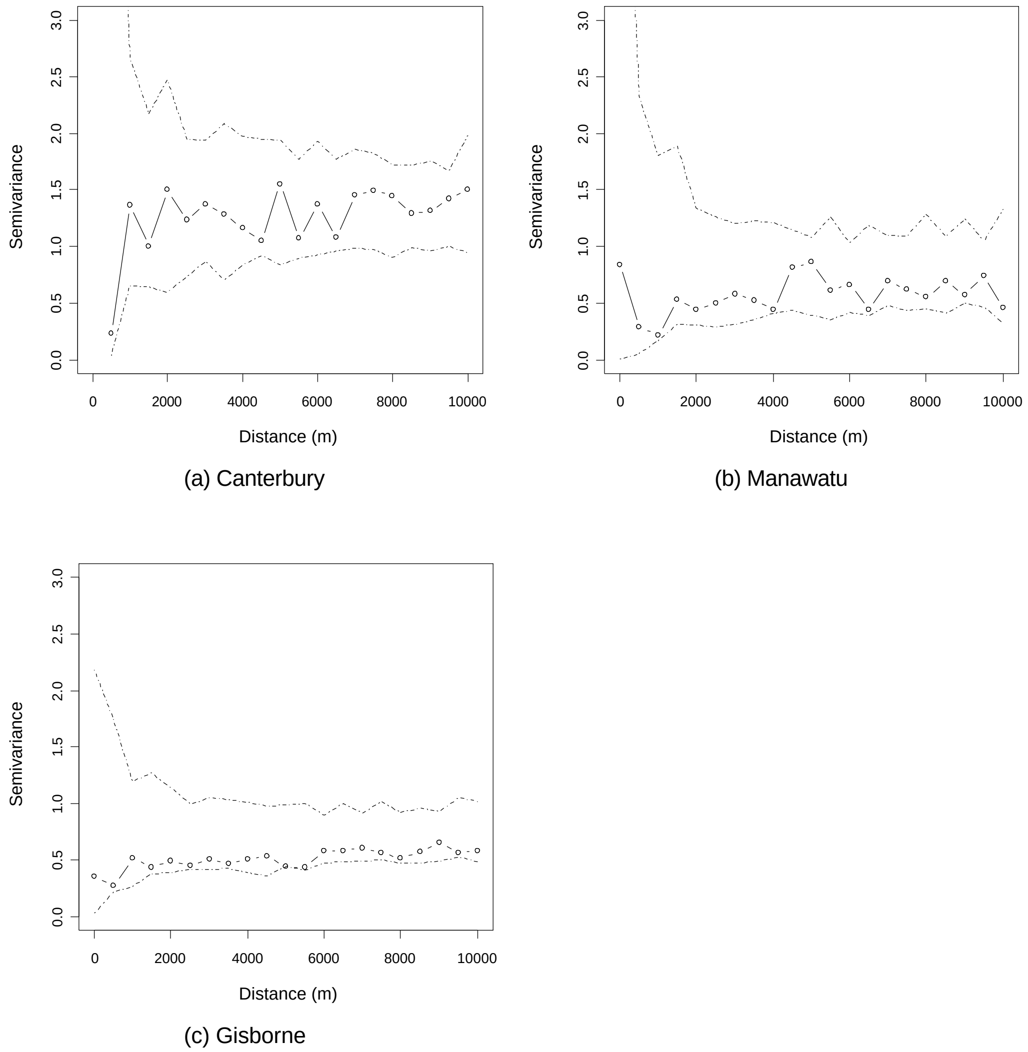

Figure 1 Binned directional variograms computed using standardized residuals from a multilevel model of the effects of processing plant and month on proportion of moderate to severe pneumonia in lambs at mob and flock-level for Canterbury (a), Manawatu (b) and Gisborne (c) with permutation-based 95 % confidence region (---).

References

Black, H. (1997) *Surveillance,* **24,** 5-8.

Goodwin, K. A., Jackson, R., Brown, C., Davies, P. R., Morris, R. S. and Perkins, N. R. (2004) *New Zealand Veterinary Journal,* **52,** 175-179.

Isaacs, E. and Srivistava, R. (1989) Oxford University Press, London, pp. 374.

Kulldorff, M. (2003).

Rasbash, J., Browne, W., Healy, M., Cameron, B. and Charlton, C. (2004) © Multilevel Models Project Institute of Education, London.