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Determination of farm-level risk factors for abnormalities observed during post-mortem meat inspection of lambs: a feasibility study

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SUMMARY

To investigate the feasibility of using information about the health and management of lambs on farms to predict the risk of gross abnormalities at post-mortem meat inspection, 6732 lambs from 30 different farms in Great Britain were followed through to slaughter in 1995/6. The farm-level data were collected during farm visits at the beginning of the study. Routine meat inspection findings for the lambs were obtained from the 10 participating abattoirs. The most common abnormalities found during post-mortem inspection were pneumonia/pleurisy (53% of cohorts), lungworm (40%), abscesses (30%), liver fluke (27%) and nephritis/nephrosis (27%). The farm-level risk factors associated with abnormalities at slaughter varied with the type of lesion. The most significant risk factor was the age of the lambs at slaughter. Lambs slaughtered at an older age were more likely to have an abnormality, especially pneumonia, abscesses and liver fluke. After age, environmental factors appeared to be better predictors of those cohorts that would have lesions at slaughter than health and disease control variables. However, a much larger study would be required to identify a set of farm-level factors that adequately discriminated between lambs with high and low risks of lesion at slaughter. At the end of the study, the farmers were informed of the meat inspection findings for their lambs and a third indicated that they would improve their animal husbandry as a result of the information.

INTRODUCTION

The current system of meat inspection has remained largely unchanged since the beginning of the century [1]. It comprises an inspection at the slaughterhouse of each animal before and after it is slaughtered. Ante-mortem inspection involves a clinical examination of the live animal to prevent obviously sick or abnormal animals entering the food chain. Post-mortem inspection entails a visual inspection of the carcase together with palpation and incision of tissues. Its aim is to detect and remove visible lesions or defects, which could affect the safety and wholesomeness of meat for human consumption.

Over the last 20 years, the cost-effectiveness of traditional meat inspection procedures has come under increasing scrutiny [2–4]. Studies have shown that the ability of many organoleptic meat inspection procedures to detect macroscopic lesions in carcases and viscera is low [4]. Moreover, the zoonotic diseases that the system was designed to detect, such as tuberculosis and cysticercosis, are now rare in developed countries. The new threats to human health

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are zoonotic micro-organisms such as *Salmonella* serotypes, *Campylobacter* spp. and verotoxigenic *Escherichia coli*, which are carried asymptomatically by animals. As these pathogens are not detected by organoleptic meat inspection, new approaches are required to reduce their levels in meat. There is also concern that the palpation and cutting of the carcase and organs during meat inspection increases the opportunity for microbial cross-contamination of carcases with these organisms [3].

Currently each carcase is subjected to the same inspection procedures regardless of the origin or the age of the animal. However, a more detailed examination may be needed for an older lamb from a flock with a history of pneumonia than for a spring lamb from a disease-free flock. To improve the cost-effectiveness of meat inspection, it has been suggested that knowledge about the health and management of food animals on the farm could be used to determine those animals entering a slaughterhouse that are likely to have gross abnormalities at slaughter [5]. With this information, meat inspectors could reduce the invasive inspection procedures carried out on animals that present a low risk to human health and focus their attention on high-risk animals. Microbial cross-contamination of carcases would be reduced and the resources saved could be used on hygiene measures to reduce microbial hazards in the slaughterhouse.

The use of clinical examination of animals on the farm to predict which animals may have abnormalities at slaughter has been investigated in pigs [5] and lambs [6]. In this paper, we present the results of a study, which examined the feasibility of using a broad range of information about the health and management of lambs on farms to predict the risk of gross abnormalities at post-mortem meat inspection. We also considered whether the health status of lambs presented for slaughter might be improved if farmers had knowledge of the meat inspection findings in their livestock.

MATERIALS AND METHODS

Study design and population

The study was carried out using a prospective longitudinal design. Data were collected about the health and management of lambs on 48 farms in Great Britain from 1995–6. When the lambs were slaughtered, routine post-mortem meat inspection findings were obtained for the animals from the abattoir. Bivariate and multivariate analyses were used to determine significant farm-level risk factors for the most common abnormalities observed in cohorts of lambs at slaughter.

Only farmers who marketed lambs of 12 months of age or less directly to known abattoirs were selected for the study. Potential participants were identified by abattoirs and marketing groups, and those farmers who were willing to co-operate were included in the study. Farmers were enrolled in the study between July 1995 and June 1996. Shortly after enrolment, the farmer was visited and asked to nominate a group or cohort of lambs, that would be sent for slaughter before December 1996.

Collection of farm data

All farm-level data were collected by the same person (D. S. Edwards) at the time of the initial visit to the farm. At the visit, data on the farm environment, standard of animal husbandry, and on the disease history and medication of the animals were obtained from the farmer or farm manager using a questionnaire (available from first author upon request).

The animals, their environment and their feed, were also assessed visually. An illustrative list of the potential risk factors ascertained during the farm inspection and farmer interview is given in Table 1.

At the interview, farmers were supplied with yellow forms to be handed into the lairage of the abattoir with each batch of animals that was sent for slaughter. On the yellow form, the farmer recorded the number and average age of the lambs in the batch and indicated whether any medication had been administered to the animals or whether they had shown signs of illness since the time of the farm visit.

Collection of post-mortem meat inspection data

At the abattoir, meat inspectors applied their usual procedures for the detection and recording of abnormalities in lambs to each batch of lambs in the study [7]. The data, which were recorded on a specially designed form, comprised the name of the abattoir, the date of inspection, the farm identification number, the total number of lambs slaughtered and the number of lambs with an abnormality. The number of lambs in each batch that were free from any abnormalities was also recorded.

Table 1. *Description of potential predictor variables used in the study*

Farm factors
Region (South West England, South East England, Wales, or Scotland and North England)
Total area of holding (hectares)
Farm area used for sheep enterprise (hectares)
Farm area grazed by cohort of lambs (hectares)
Number of stock persons
Arable enterprise on same holding as lambs (yes/no)
Dairy enterprise on same holding as lambs (yes/no)
Beef fattening or suckler enterprise on same holding as lambs (yes/no)
Farm terrain mostly hilly (yes/no)
Farm fields often waterlogged or poached (yes/no)
Cats present on the farm (yes/no)
Hunt has access to the farm (yes/no)
Public footpaths present on the farm (yes/no)
Public amenities, e.g., picnic areas, on or near the farm (yes/no)
Farm environment generally clean (yes/no)
Dogs
Number of dogs on farm
Dogs on the sheep farm have access to dead sheep (yes/no)
Proportion of dogs on farm wormed over last two years (all, some, none, not known or not applicable)
Dog worming regime effective against hydatids (yes, no, not known or not applicable)
Dogs given praziquantel (yes/no)
Management of cohort
Number of lambs in cohort
Average age of cohort at slaughter
Cohort contained female lambs
Cohort contained castrated lambs
Cohort contained entire lambs
Cohort housed from birth to slaughter
Mains water used as a source of drinking water for the cohort (yes/no)
Well or bore water used as a source of drinking water for the cohort (yes/no)
Water from a stream or river used as a source of drinking water for the cohort (yes/no)
Water from a spring used as a source of drinking water for the cohort (yes/no)
Feed
Lambs fed hay (yes/no)
Lambs fed silage (yes/no)
Lambs fed concentrates, e.g., pellets (yes/no)
Forage crops grown (yes/no)
Forage rape grown (yes/no)
Toxic plants in pasture or forage crop (yes/no)
Ragwort in pasture or forage crop (yes/no)
Bracken in pasture or forage crop (yes/no)
Soil deficient in trace elements (yes/no)
Soil deficient in cobalt (yes/no)
Soil deficient in selenium (yes/no)
Farmyard manure applied to pasture over last two years (yes/no)
Health status of cohort
One or more lambs in cohort with signs of illness pre-weaning (yes/no)
One or more lambs in cohort with coughing pre-weaning (yes/no)
One or more lambs in cohort with a runny nose pre-weaning (yes/no)
One or more lambs in cohort with diarrhoea pre-weaning (yes/no)
One or more lambs in cohort with joint/navel ill pre-weaning (yes/no)

[*continued overleaf*

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Table 1 (*cont*.)

One or more lambs in cohort with signs of illness post-weaning (yes/no)
One or more lambs in cohort with coughing post-weaning (yes/no)
One or more lambs in cohort with diarrhoea post-weaning (yes/no)
Disease prevention and control
Navels of lambs treated with iodine and/or antiseptic (yes/no)
Cohort vaccinated against pneumonia (yes/no)
Cohort vaccinated against clostridial diseases (yes/no)
Cohort given anthelmintics effective against lungworm (yes/no)
Cohort given anthelmintics effective against liver fluke (yes/no)
Cohort given prophylactic treatment against fly strike (yes/no)
Cohort dipped against ectoparasites (yes/no)
One or more lambs in cohort given antibiotic treatment (yes/no)
One or more lambs in cohort given coccidiostats (yes/no)
One or more lambs in cohort treated for pneumonia (yes/no)
Past disease history of cattle and sheep on farm
Lungworm ever occurred (yes/no)
Liver fluke ever occurred (yes/no)
Cysticercus ovis ever occurred (yes/no)
Cysticercus tenuicollis ever occurred (yes/no)
Hydatids ever occurred (yes/no)
Leptospirosis occurred in last two years (yes/no)

Table 2. *Number of cohorts and lambs with post-mortem meat inspection reports and proportion with one or more abnormalities found at slaughter in each of 10 abattoirs*

Abattoir	Number (%) of cohorts inspected	Number (%) of cohorts with abnormalities	Number (%) of lambs inspected	Number (%) of lambs with abnormalities
1	1 (3·3)	1 (100·0)	1014 (14·4)	99 (9·8)
2	1 (3·3)	0 (0·0)	3 (0·1)	0 (0·0)
3	5 (16·7)	1 (20·0)	694 (9·8)	9 (1·3)
4	2 (6·7)	1 (50·0)	220 (3·1)	8 (3·6)
5	7 (23·3)	7 (100·0)	2399 (34·0)	30 (1·2)
6	6 (20·0)	5 (83·3)	592 (8·4)	176 (29·7)
7	4 (13·3)	4 (100·0)	1500 (21·3)	460 (30·7)
8	1 (3·3)	1 (100·0)	329 (4·7)	216 (65·6)
9	2 (6·7)	1 (50·0)	253 (3·6)	66 (26·1)
10	1 (3·3)	1 (100·0)	42 (0·6)	5 (11·9)
Total	30 (100·0)	22 (73·3)	7046 (100·0)	1069 (15·2)

Farm follow-up survey

When all animals in the study had been slaughtered, the farmer was sent a summary of the meat inspection findings and a questionnaire designed to determine whether the information would cause the farmer to change any farm practices. Three questions were asked: (i) will the routine medication (e.g. vaccination or worming) for the flock be modified; (ii) will the anthelmintic treatment used for any dogs on the farm be modified and (iii) will any other farm practices be changed? The answers were obtained by telephone two weeks after sending out the questionnaire.

Statistical analyses

The cohort of lambs followed through to slaughter from each farm was used as the unit of analysis. Lambs in each cohort were slaughtered in batches over a period of time. The age at slaughter of the cohort was taken as the average age of all batches for the cohort.

The data from the farm questionnaire and the post-mortem meat inspection findings were entered into a database, Epi-Info 6 [8]. The different abnormalities detected at post-mortem meat inspection comprised the outcome variables for the study. A cohort of lambs was considered positive for the abnormality if it was detected at slaughter in at least one lamb in the cohort.

Bivariate analysis was performed using Epi Info 6 [8]. The association between each potential risk factor and a cohort having at least one lamb with an abnormality at slaughter was examined using Yates corrected χ^2 test or where appropriate, Fisher's exact test. Means were calculated for non-categorical risk factors and tested for a significant difference using Student's t test or Kruskal–Wallis test. The level of significance was set at 0·05 (two-tailed test).

To evaluate potential confounding factors and interactions among farm-level risk factors, unconditional multiple logistic regression analysis was performed using the statistical software package, Egret [9]. To determine the best-fitting model, the most significant risk factor in the bivariate analysis was entered into the model first. Thereafter, each of the remaining factors was added to the model containing the first factor to test whether its addition significantly improved the fit of the model. The factor with the highest likelihood ratio statistic (χ^2 with 1 D.F.) was selected for addition to the model and the process was repeated. Factors with a P value of less than 0·05 entered the model. Following fitting of the main effects model, all two-way interactions between factors were added to the model and tested for significance together with all lower degree terms. The logistic regression model equation was used to calculate the risk of a cohort of lambs having an abnormality that could be detected at slaughter.

RESULTS

Post-mortem meat inspection data were obtained for 7046 lambs from 30 (62·5 %) of the 48 farms originally enrolled in the study. The results that follow refer to the 30 cohorts of lambs (1 cohort per farm) for which post-mortem meat inspection data were received. These lambs comprised 29 % of the 24294 lambs destined for slaughter (on the 30 farms) at the beginning of the study.

Post-mortem meat inspection findings

Lambs from the 30 farms were sent to 10 different abattoirs, 3 of which slaughtered 70 % of the lambs in the study (Table 2). The mean number of lambs inspected per cohort was 235 (median 188, range 3–1014). At post-mortem inspection, abnormalities were found in at least one lamb from 22 (73·3 %) of the 30 cohorts in the study and in 15 % of the 7046 lambs for which post-mortem inspection data were available (Table 2).

Table 3. *Frequency distribution of abnormalities found in cohorts of lambs at post-mortem meat inspection*

Type of abnormality	Number of cohorts	Proportion of total cohorts (%)
Pneumonia/pleurisy	16	53·3
Lungworm	12	40·0
Abscesses	9	30·0
Liver fluke	8	26·7
Nephritis/nephrosis	8	26·7
Cysticercus tenuicollis	7	23·3
Contamination	7	23·3
Cysticercus ovis	5	16·7
Peritonitis	4	13·3
Arthritis	3	10·0
Trauma	3	10·0
Hydatids	1	3·3
Other abnormalities	5	16·7

The most common lesions found in the lambs were pneumonia/pleurisy, lungworm, abscesses, liver fluke, nephritis/nephrosis and the dog-borne tapeworm cysts *Cysticercus ovis*, *Cysticercus tenuicollis* and hydatids (Table 3). All 12 cohorts with evidence of lungworm at slaughter also had lesions of pneumonia and/or pleurisy recorded.

Factors associated with abnormalities at slaughter

Bivariate analysis

The farm-level variables found to be significantly associated ($P < 0{\cdot}05$) with the different abnormalities at slaughter are presented in Tables 4 and 5 for categorical variables and in Table 6 for non-categorical variables. Risk factors varied considerably among the different types of lesion detected at slaughter. However, lambs slaughtered at an older age were more likely to have pneumonic lesions, abscesses and liver fluke detected at post-mortem meat inspection.

Multivariate analysis

Because many significant risk factors had a zero value in the bivariate analysis and the sample size was small,

Table 4. *Significant categorical farm-level risk factors associated with abnormalities detected in cohorts of lambs at post-mortem meat inspection*

Risk factor	Number of cohorts	Prevalence (%)				
		Any abnormality	Pneumonia	Abscesses	Liver fluke	Nephritis/ nephrosis
Region						
South West England	6	100·0	83·3	50·0	33·3	33·3
South East England	12	58·3	41·7	0·0**	0·0**	8·3
Wales	6	50·0	16·7	16·7	0·0	33·3
Scotland, North England	6	100·0	83·3	83·3**	100·0**	50·0
Farm terrain						
Mostly hilly	7	85·7	71·4	57·1	71·4**	42·9
Mostly flat	23	69·6	47·8	21·7	13·0	21·7
Housing of cohort						
Continuous over lifetime	5	40·0	0·0*	0·0	0·0	20·0
Not housed	25	80·0	64·0	36·0	32·0	28·0
Entire lambs						
Present in cohort	7	57·1	14·3*	14·3	14·3	28·6
Not present in cohort	23	78·3	65·2	34·8	30·4	26·1
Stream, spring or pond water						
Drunk by cohort	24	83·3*	62·5	33·3	33·3	25·0
Not drunk by cohort	6	33·3	16·7	16·7	0·0	33·3
Cohort						
Grazed forage crops	12	91·7	83·3*	50·0	50·0*	41·7
Did not graze forage crops	18	61·1	33·3	16·7	11·1	16·7
Cohort						
Grazed forage rape	7	100·0	100·0**	71·4*	57·1	57·1
Did not graze forage rape	23	65·2	39·1	17·4	17·4	17·4
Toxic plants						
Present in pasture	11	90·9	81·8*	45·5	54·5*	36·4
Not present in pasture	19	63·1	36·8	21·1	10·5	21·1
Bracken						
Present in pasture	9	100·0*	88·9*	55·6	66·7**	44·4
Not present in pasture	21	61·9	38·1	19·0	9·5	19·0
Soil						
Deficient in cobalt	4	100·0	100·0	75·0	75·0*	75·0*
Not deficient in cobalt	26	69·2	46·2	23·1	19·2	19·2
Illness post-weaning						
Reported in cohort	9	88·9	88·9*	44·4	44·4	33·3
Not reported in cohort	21	66·7	38·1	23·8	19·0	23·8
Pasteurella vaccines						
Used in cohort	11	81·8	81·8*	54·5*	45·5	45·5
Not used in cohort	19	68·4	36·8	15·8	15·8	15·8
Lungworm prophylaxis						
Used in cohort	22	86·4*	72·7**	40·9	36·4	31·8
Not used in cohort	8	37·5	0·0	0·0	0·0	12·5
Lungworm						
Occurred in last two years	8	100·0	87·5*	37·5	25·0	12·5
Not occurred in last 2 years	22	63·6	40·9	27·3	27·3	31·8
Salmonellosis						
Occurred on farm before	8	87·5	62·5	62·5*	37·5	37·5
Not occurred	22	68·2	50·9	18·2	22·7	22·7
Leptospirosis						
Occurred in last two years	5	100·0	80·0	100·0**	100·0**	80·0*
Not occurred in last 2 years	25	68·0	48·0	16·0	12·0	16·0

* Variables with $P < 0{\cdot}05$.
** Variables with $P < 0{\cdot}01$.

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Table 5. *Significant categorical farm-level risk factors associated with cohorts of lambs having* Cysticercus ovis, Cysticercus tenuicollis *or any dog-borne tapeworm cyst (includes hydatids) detected at post-mortem meat inspection*

Risk factor	Number of cohorts	Prevalence (%) *Cysticercus ovis*	*Cysticercus tenuicollis*	Dog-borne tapeworm cysts
Region				
South West England	6	66·7**	33·3	66·7
South East England	12	0·0	0·0*	0·0**
Wales	6	0·0	50·0	50·0
Scotland, North England	6	16·7	33·3	66·7
Arable enterprise				
Present on farm	21	4·8*	14·3	23·8*
None	9	44·4	44·4	66·7
Dairy enterprise				
Present on farm	6	50·0*	50·0	66·7
None	24	8·3	16·7	29·2
Dogs on farm				
Have access to dead sheep	9	44·4*	11·1	55·6
Do not have access to dead sheep	21	4·8	28·6	28·6
Farmyard manure				
Applied to pasture	19	26·3	31·6	52·6*
Not applied to pasture	11	0·0	9·1	9·1
Mains water				
Drunk by cohort	20	5·0*	20·0	30·0
Not drunk by cohort	10	40·0	30·0	50·0
Public footpath				
Present on farm	22	4·5*	22·7	31·8
None	8	50·0	25·0	50·0
Leptospirosis				
Occurred in last two years	5	40·0	40·0	80·0*
Not occurred in last two years	25	12·0	20·0	28·0

* Variables with $P < 0{\cdot}05$.
** Variables with $P < 0{\cdot}01$.

it was not possible to construct definitive farm-level logistic regression models for the different abnormalities detected at slaughter. To illustrate how farm-level information about lambs might be used to determine the cohorts that would be likely to have gross lesions at post-mortem meat inspection, the logistic regression model for any abnormality at slaughter is presented in Table 7.

The only risk factor significantly associated ($P < 0{\cdot}05$) with an increased risk of a cohort having an abnormality detected at inspection was the average age of the cohort at slaughter. For each 1-month increase in age, the odds of a cohort having at least one lamb with an abnormality detected at slaughter increased 2·39 times. For cohorts slaughtered at 3 months of age, there was a 35% risk of a cohort having an abnormality found at slaughter. By 6 months of age, the risk had risen to 88% and by 9 months of age, it was 99%.

Feedback of information to farmers

The response of farmers to the receipt of the meat inspection findings in their lambs was obtained by telephone. Seven of the 30 farmers said that they would alter the routine medication for the sheep in the light of the meat inspection findings, and 5 of the 7 farmers consulted their veterinary surgeon for advice on sheep medication. Eight farmers said that they planned to administer an anthelmintic to their dogs that was effective against *Taenia* spp. and hydatid tapeworms. Four of these farmers intended to consult

Table 6. *Significant non-categorical, farm-level risk factors associated with abnormalities detected in cohorts of lambs at post-mortem meat inspection*

Risk factor	Cases mean (standard deviation)	Non-cases mean (standard deviation)
Any abnormality	$n = 22$	$n = 8$
Average age of cohort at slaughter (months)	6·2 (1·9)**	3·9 (1·1)
Farm area grazed by cohort (hectares)	202·9 (319·9)*	38·6 (47·0)
Pneumonia	$n = 16$	$n = 14$
Average age of cohort at slaughter (months)	7·1 (1·2)**	3·9 (0·9)
Abscesses	$n = 9$	$n = 21$
Average age of cohort at slaughter (months)	7·0 (1·6)**	5·0 (1·8)
Liver fluke	$n = 8$	$n = 22$
Average of cohort at slaughter (months)	7·5 (1·2)**	4·9 (1·8)
Dog-borne tapeworm cysts	$n = 11$	$n = 19$
Farm area grazed by cohort (hectares)	308·4 (431·3)*	72·7 (65·1)
Number of stock persons employed on farm	2·9 (1·4)*	1·9 (0·7)
Cysticercus ovis	$n = 5$	$n = 25$
Number of stock persons employed on farm	3·2 (1·1)*	2·1 (1·0)

* Variables with $P < 0{\cdot}05$.
** Variables with $P < 0{\cdot}01$.

Table 7. *Farm-level logistic regression models for abnormalities detected at post-mortem meat inspection of 30 cohorts of lambs*

Variable	β-coefficient	S.E. (β)*	Odds ratio	95% CI† (odds ratio)
Constant	−3·24	1·63	—	—
Age at cohort at slaughter (months)	0·87	0·36	2·39	1·18–4·83

* S.E., standard error.
† CI, confidence interval.

with a veterinarian for advice. A routine farm practice other than medication, for example allowing farm dogs access to sheep carcases, was to be changed on 7 farms as a result of the meat inspection findings. In three cases, the farmers sought veterinary advice.

DISCUSSION

Because of the difficulty in tracing lambs in the slaughterhouse back through markets and dealers to their farms of origin, we followed cohorts of lambs from the farm of origin through to slaughter. Farmers who used dealers or markets were excluded from the study to avoid uncertainty. This and the use of cooperative farmers meant that the results were probably not representative of the national population of slaughter lambs. However, the main objective of the study was to examine the feasibility of using information about the health and management of lambs on the farm to predict the risk of visible lesions at slaughter. There was no intention to determine a definitive set of risk factors, since this was not considered critical to the purpose of the study.

A common problem with prospective longitudinal studies is the loss to follow-up of some of the subjects. In this study, we did not obtain post-mortem meat inspection data for lambs from 18 (37·5%) of the 48 farms originally enrolled in the study. Over 70% of lambs from the 30 cohorts that were successfully followed to slaughter were also missed at the abattoir. Identification of the study lambs at the abattoir relied on farmers or their hauliers handing in a yellow identification form at the lairage. Some farmers omitted to send the yellow form with their lambs. However, more commonly the problem lay with the hauliers who did not hand in the yellow forms, or who handed them in with other documentation at the abattoir office instead of the lairage. Since numerous hauliers were used by the farmers, it was not feasible to explain procedures directly to them. We considered tagging the study lambs on the farm to facilitate identification at the abattoir, but the option was not pursued, mainly because of cost, but also because additional tagging of the animals might be viewed as unnecessary mutilation. Data were lost from seven farms when one meat inspection team later declined to participate in the study.

Since many risk factors analysed in the study applied to the farm or the flock, data were collected and analysed for a cohort of lambs from each farm rather than for individual animals. This approach proved problematic for those risk factors that differed among the animals in a cohort, for example, sex, disease occurrence, medications. To reduce some within-cohort variation, all lambs in a cohort had to be born on the farm in the same season. However, a cohort could contain entire male, castrated male and/or female lambs. If a management practice, treatment or disease was applied to at least 1 lamb in a cohort, it was considered to have occurred in the cohort as a whole. Similarly, no distinction was made between events that occurred in the cohort once or many times. For example, a cohort was coded as treated for lungworm, whether it had been drenched once or 3 times between birth and slaughter, and whether 1 animal or all animals in the cohort had been treated.

In any system of meat inspection that uses information about the health and management of lambs on the farm, a decision will be required on whether to record data on a flock basis or from individual animals. It is expensive to keep extensive records for individuals animals, which must be identified. However, the power to discriminate between flocks with and without abnormalities at slaughter on the basis of animal characteristics is diminished by averaging information across the flock or by recording risk factors on the basis of what applies to a proportion of the flock. If individual animal recording was instituted on farms, it would have to be matched by a more detailed inspection of suspect lambs at the slaughterhouse. To facilitate this process, Green and colleagues [6] suggested that animals treated for disease should be tagged to indicate the need for a more extensive post-mortem inspection at the abattoir.

At meat inspection, there was considerable variation among the 10 abattoirs in the proportion of cohorts and lambs with one or more abnormalities. The proportion of cohorts with any abnormalities ranged from zero to 100% and that for lambs with specific abnormalities from zero to 66%. The variation among abattoirs may reflect real differences in the health and management of lambs from different areas of Great Britain, but it could have been caused by differences in meat inspection practice among abattoirs. In a study in seven abattoirs in England in 1980, there was considerable variation among the abattoirs with respect to the amount of pig meat and viscera rejected [10]. The authors suggested that differences in the meat inspectors' assessment of carcase pathology may have accounted for much of the variation.

Our study coincided with the first year of operation of the Meat Hygiene Service, which took over from local authorities the hygiene, inspection and welfare responsibilities in licensed fresh meat plants in Great Britain on 1 April 1995. Since an objective of the agency is to improve consistency of meat inspection between abattoirs in Great Britain [11], the potential confounding effect of different abattoir inspectors on the prevalence of abnormalities detected at post-mortem meat inspection should diminish. The effect of the different abattoir inspection teams on the probability of a cohort having an abnormality detected at slaughter in the statistical analysis could not be investigated because of the large number of abattoirs and small number of farms in the study.

The farm-level risk factors associated with abnormalities at slaughter varied with the nature of the lesion. The most significant farm-level risk factor influencing post-mortem meat inspection findings was the age of the lambs at slaughter. The risk of a cohort of lambs having any abnormality or lesions of pneumonia/pleurisy, abscesses and liver fluke all increased with increasing age of the cohort at slaughter. This finding was not unexpected as older lambs have more opportunity for exposure to pathogens and more time in which to develop lesions. The age and time of year when lambs are slaughtered often reflects the type of animal husbandry system used and this in turn may affect the disease status of the animals. Lambs slaughtered at 3–4 months of age are mainly 'early lambs' marketed in late March and early April when prices are higher. They are usually reared indoors. Lambs reaching an age of 7 months or more before slaughter often originate from extensive

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husbandry systems with relatively harsh environmental conditions. In a longitudinal study of diseases in lambs, Green and colleagues [6] found that older lambs, which had taken longer to mature, had a significantly greater risk of arthritis, pleurisy and pneumonia lesions being detected during meat inspection.

After the age of the cohort, environmental factors appeared to play a significant role in determining the cohorts that would have lesions at slaughter. These factors included the geographic region where the cohorts were reared, the farm terrain, vegetative cover and whether or not the lambs were housed. In comparison, the health status of the animals and the disease prevention and control measures applied during rearing did not seem to be good predictors of the presence of lesions at slaughter. A similar observation was made by Green and colleagues [6] who found a lack of association between observable disease in live lambs and lesions at slaughter.

In some cases, the association between disease control and the presence of abnormalities at slaughter was perverse. For example, cohorts were more likely to have pneumonic lesions at slaughter if they had been vaccinated against pneumonia. This association probably reflected the increased propensity of farmers to vaccinate their lambs against pneumonia if the disease was a particular problem on the farm.

The increased risk of *Cysticercus ovis* lesions in lambs from farms where the dogs had access to sheep carcases is indicative of the life cycle of the dog tapeworm *Taenia ovis*. The sheep is the intermediate host for *Taenia ovis* and dogs become infected with the tapeworm by eating sheep carcases infected with cysticerci [12]. The significant association between leptospirosis occurring in livestock on a farm and the presence of nephritis/nephrosis lesions in the lambs at slaughter may also be a causal one. Nephritic lesions due to leptospirosis have been described in cattle by Amatredjo and colleagues [13] and in sheep, cattle and goats by Burdin [14]. Further investigation of the association between leptospirosis in livestock on farms and kidney lesions in lambs from such farms may be merited.

Essentially, this study was conducted to investigate the feasibility of using a broad range of information about the health and management of lambs on farms to predict the risk of abnormalities at post-mortem meat inspection. Many farm-level factors were investigated, but, because of the small sample size, it was not possible to determine the important risk factors among the many correlated variables. The age of the cohort at slaughter was the only important predictor of the presence of an abnormality at slaughter after allowing for other factors in the analysis. If the results of this study are representative of the slaughter lamb population in Great Britain, an abnormality would be detected at post-mortem inspection in about one third of cohorts slaughtered at 3 months of age. Over half the flocks slaughtered at 4 months of age would contain at least one lamb with a lesion. In cohorts slaughtered at 5 months of age or more, over 75% of the cohorts would have a lesion detected at slaughter. Clearly, if on-farm information is to be used to decide on the lambs that need to undergo a more thorough post-mortem inspection, a set of factors is required that adequately discriminate between lambs with a high and low risk of abnormalities at slaughter. This study has indicated the variables that may be useful predictors of gross lesions in cohorts of lambs at slaughter, but a much larger study would be required to fully identify the definitive predictors.

During the interviewing of farmers and farm managers for this study, it became apparent that only 25% of the farms visited had livestock medicine books which were properly completed and up to date. Other farm records relating to symptoms of sickness in lambs were rarely kept. In any further studies, the problem of poor record keeping on farms would have to be addressed if a valid assessment were to be made and any system of on-farm certification of livestock introduced.

None of the abattoirs in the study regularly passed the results of post-mortem meat inspection onto farmers. However, farmers in the study indicated that they would have liked to receive the meat inspection findings for their lambs and a third of them said that they would improve their animal husbandry practice as a result of the information. Therefore, it appears that the health status of lambs presented for slaughter might be improved if farmers had knowledge of the meat inspection findings from their livestock. In a study in Australia, Paton and colleagues [15] demonstrated a quantitative improvement in the health status of slaughter lambs from farmers informed of the relevant meat inspection findings.

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