Post mortem meat inspection for tuberculosis in farmed red deer: some implications for animal health surveillance

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Introduction

Control of *Mycobacterium bovis* in domestic livestock in New Zealand presents a difficult problem. Wild and feral species of animals form reservoirs of infection that continually have the potential to transfer *M. bovis* to farmed deer and cattle, thereby severely limiting the effectiveness of test and slaughter alone as a means to reduce the prevalence of infection to "acceptable" levels. More sophisticated means of control, in terms of reducing transfer of infection from wild and feral species and in terms of reducing on-farm transmission within and between domestic species, are required (Livingstone, 1991; Morris and Pfeiffer, 1991). Effective slaughterhouse monitoring and surveillance of the slaughter deer population provides an essential contribution to any targeted control programme.

Notwithstanding animal health monitoring and surveillance needs for control of *M. bovis* all farmed deer slaughtered in licensed slaughterhouses must receive a comprehensive post mortem inspection in order that the carcass and offals can be judged as safe for human consumption. If reactor deer are slaughtered, special hygienic practices must be followed and more intensive post mortem inspection procedures applied. Judgements are made on an animal-by-animal basis. Most international markets exclude reactor deer from the export trade, irrespective of post mortem inspection findings.

It is therefore clear that post mortem meat inspection has two goals; providing essential information for animal health monitoring and surveillance purposes, and satisfying food safety and certification requirements for venison products in international and local trade. The meat inspection activities and judgements undertaken to satisfy these goals are not necessarily mutually exclusive, and particular activities may perform differently relative to each goal.

The research programme from which this paper is drawn was aimed at increasing knowledge on all aspects of cervine and bovine post mortem meat inspection activities as they relate to public health and animal health. The slaughterhouse database that was developed for farmed red deer accumulated information on all suspect tuberculous animals slaughtered in licensed slaughterhouses between June 1990 and October 1993. A preliminary analysis of the outcomes of post mortem meat inspection and some of the implications for monitoring and surveillance for animal health purposes is presented here.

Materials and methods

Database

A system was developed for recording slaughterhouse data and integrating information flows for all post mortem meat inspection activities, animal health field activities and laboratory diagnostic activities relating to farmed red deer suspected of being tuberculous (Anonymous, 1989). The data were accumulated in a centralised relational database using a hierarchical model that allowed analysis at the herd, slaughter line, animal or lesion level.

Animal data included identification number, slaughter class (reactor or non-reactor), origin according to the designated special tuberculosis control areas in New Zealand (endemic, fringe, non-endemic [Livingstone, 1991]), herd type (breeding, velveting, safari etc.), age (1 year, 2 to 3 years, > 3 years), sex (stag or hind), and skin test and episode history of the herd. Reactor animals were not differentiated as to whether an ancilliary test (comparative cervical test or blood test) was performed subsequent to the skin test.

All post mortem inspection data were recorded in "hard boxes" and included gross findings and distribution of lesions according to 23 possible anatomical sites. All gross lesions suspicious of tuberculosis were forwarded for laboratory examination (fresh and fixed samples) and diagnostic data included. the outcomes of HE histology (typical, suspicious or negative haematoxylin and eosin-stained tissue sections), ZN histology (positive or negative Ziehl-Neelsen acid-fast smears), and culture. *Mycobacterium* spp. that were isolated were identified as *M. bovis*, *M. avium* complex or "other".

For purposes of analysis, new variables were established for lesion data from each animal according to whether or not a lesion was found in the "primary complex" sites of the head (retropharyngeal, submaxillary or parotid lymph nodes), thorax (bronchial or mediastinal lymph nodes) and abdomen (ileo-caecal or ileo-jejunal lymph nodes).

Case definition for analysis of anatomical distribution of lesions

The sensitivity and specificity of HE and ZN histology were determined from data from all red deer, stratified by area of origin, from which one or more tissue samples were culture positive. The values for sensitivity and specificity were then used to derive positive predictive values (PPVs) (Dawson-Saunders and Trapp, 1994) in the sub-populations that had not been cultured. Sub-populations having PPVs equal to or greater than 90% were included in the analysis.

Associations between animal and environmental factors, and distribution of lesions

The primary investigation of these associations utilised contingency tables; in some cases with a further stratification variable. Further analyses involved path modelling to investigate the relationships between variables (Curtis and others, 1993), and this work will be reported in greater detail elsewhere.

Analysis of performance characteristics of histological tests

Deer from which at least one tissue sample had been cultured were used for this analysis. The sensitivity of HE histology was calculated by designating "HE suspicious" as a negative result. Thus the sensitivity of HE histology was the proportion of HE positive animals that were positive on culture for *M. bovis*. The sensitivity of ZN histology was the proportion of ZN positive animals that were positive on culture for *M. bovis*. Specificities were the proportions of HE negative (including HE suspicious) and ZN negative animals that were negative on culture for *M. bovis*.

A positive predictive value (PPV) for a screening test is the probability that a positive test result has identified an infected animal, and a negative predictive value (NPV) is the probability that a negative test result has identified a non-infected animal. Predictive values were calculated for the proportions of HE positive, HE suspicious, and HE negative animals that were positive on culture for *M. bovis*. Predictive values for the proportion of ZN positive and ZN negative animals were similarly calculated.

As well as being influenced by sensitivity and specificity, predictive values are influenced by the prevalence of infection in the population of interest. Multivariate logit analysis was used to allow for confounding while further investigating the various associations between the performance characteristics, and their possible range. This work will be reported in detail elsewhere. The relationship between PPVs for histological screening tests and the true prevalence of *M. bovis* was modelled using the @RISK PC software programme (Palisade Corporation, New York).

Results

Database

A total of 5175 records were accumulated in the database; 3462 for test reactors (67.5%) and 1683 for routine slaughter animals (32.5%). The area of origin was available for 5007 deer: 1999

originated from endemic areas, 702 originated from fringe areas, and 2306 originated from non-endemic areas.

Gross post mortem inspection findings were recorded for 5023 deer. Histological and culture results were available for 1521 and 846 deer respectively A total of 483 deer were culture positive for *M. bovis*, and *M. avium* complex was isolated from a further 46 deer. "Other" mycobacteria (including *M. johnei*) were isolated from five deer.

Anatomical distribution of lesions

A total of 668 deer met the case definition for analysis of the anatomical distribution of lesions. These cases consisted of 451 animals that were culture positive for *M. bovis*, and 217 not cultured but being from sub-populations with appropriate PPVs. Gross findings typical of tuberculosis compared with equivocal gross findings were present in 86.7% of cases and the majority of deer with gross lesions that were found to be attributable to *M. bovis* were non-reactors (57.9%).

A single lesion attributable to *M. bovis* per animal was the most common gross post mortem finding (74.7% of cases), and more than two lesions per animal were rare (Table 1). No statistically significant associations were found between number of lesions and gross findings (typical or equivocal), reactor status, endemic origin, age or sex.

The anatomical distribution of lesions (Table 2) showed a marked predominance of lesions in the retropharyngeal lymph nodes (52.3%), followed by the ileo-jejunal lymph nodes (20.8%). Lesions were much less common in the ileo-caecal lymph nodes (9.7%). Lesions in the bronchial and mediastinal lymph nodes accounted for 11.1% and 10.0% of lesions attributable to *M. bovis* respectively, and lesions commonly involved the pleura and lungs (8.5% and 8.1% respectively). Much smaller numbers of lesions were widely distributed amongst other sites.

Table 1: Number of lesions attributable to *M. bovis* in red deer

Number of lesions per deer	1	2	3	4	5	6	7	8	10
Number of deer	499	105	35	9	10	4	3	2	1
Per cent	74.7	15.7	5.2	1.4	1.5	0.6	0.5	0.3	0.2

There were marked similarities in the anatomical distribution of lesions in reactor deer compared with non-reactor deer (Table 2). Some differences apparent at specific sites were a higher proportion of lesions in the retropharyngeal lymph nodes, and a lower proportion in the bronchial/mediastinal lymph nodes and pleura, in reactor deer.

Lesions attributable to *M. bovis* in primary complex sites (lymph nodes of the head, lungs and small intestine), irrespective of lesions at other sites, occurred in 91.2% of deer and the head was the most common primary complex site reported (57.0% of deer). The large majority of cases (76.3%) involved only one primary complex, and in those deer where lesions were limited to a single primary complex alone (66.6%), the head was by far the predominant site.

An analysis of the anatomical distribution of primary complex lesions using stratified contingency tables revealed some statistically significant patterns and associations (unpublished data). Of particular note was that when head primary complex lesions were present, there was a statistically significant increase in accompanying sole abdominal lesions (11.6%) compared with sole thoracic lesions (5.0%) ($P = 0.002$). When head primary complex lesions were not present, there was no significant difference in these frequencies.

Lesions attributable to *M. bovis* at sites other than those of the primary complexes occurred in 59 (8.8%) of deer. Most of these cases (91.5%) were represented by single lesions; predominantly in the prescapular lymph nodes, pleura, apical lymph nodes, superinguinal/supramammary lymph nodes or popliteal lymph nodes Lesions at any other individual sites only occurred in two or less cases.

Log linear modelling of the distribution of lesions in primary complexes and the presence or absence of non-primary lesions indicated a highly significant negative association between the presence of head primary complex lesions and non-primary lesions ($P < 0.001$, odds ratio of 0.22). In contrast, thoracic primary complex lesions were positively associated with non-primary lesions ($P < 0.01$, odds ratio 1.77).

Table 2: Anatomical distribution of lesions attributable to *M. bovis* in farmed red deer

Site	All deer		Reactor deer		Non-reactor deer	
	Number (%)*		Number (%)		Number (%)	
Retropharyngeal ln	349	52.3	161	57.3	188	48.6
Ileo-jejunal ln	139	20.8	61	21.7	78	20.2
Bronchial ln	74	11.1	25	8.9	49	12.7
Mediastinal ln	67	10.0	26	9.3	41	10.6
Ileo-caecal ln	65	9.7	38	13.5	27	7.0
Pleura	57	8.5	17	6.1	40	10.3
Lung	54	8.1	24	8.5	30	7.8
Submaxillary ln	36	5.4	16	5.7	20	5.2
Prescapular ln	31	4.6	11	3.9	20	5.2
Apical ln	18	2 7	7	2.5	11	2.8
Parotid ln	15	2.3	8	2.9	7	1.8
Hepatic ln and/or liver	14	2.1	6	2.1	8	2.1
Atlantal ln**	12	1.8	7	2.5	5	1.3
Popliteal ln	7	1.1	4	1.4	3	0.8
Inguinal/supramammary ln	4	0.7	1	0.4	3	0.8
Internal iliac ln	3	0.5	1	0.4	2	0.5
Precrural ln	2	0.3	1	0.4	1	0.3
Lumbar ln	2	0.3	0	0	2	0.5
Ischiatic ln	2	0.3	1	0.4	1	0.3
Renal ln	2	0.3	1	0.4	1	0.3
Other***	18	2.5	5	1.8	13	3.4

* Number of animals with one or more lesions

** Atlantal = Lateral pharyngeal ln

*** Pericardium, tonsils, peritoneum, heart, muscle, anal lymph nodes, diaphragm, peripheral lymph nodes of foreleg

Performance characteristics of histological tests

HE histology results were available from 1519 deer; 848 (55.8%) showed histopathological lesions typical of tuberculosis and 283 (18.6%) showed histopathological lesions suspicious of tuberculosis. ZN histology results were available from 1456 deer; 430 (29.5%) were positive for acid fast organisms. There were 826 typical HE histology cases with a corresponding ZN histology record; only 411 of these (49.8%) were ZN positive. In only one case was a ZN histology result positive but the corresponding HE histology result negative.

The performance characteristics for histological tests are given in Table 3. The sensitivity of HE histology in reactor deer was higher than that in non-reactors (0.84 versus 0.76). The sensitivity of ZN histology was much lower than for HE histology in both slaughter classes. The specificity of both histological tests was relatively low for both reactor and non-reactor deer. PPVs for HE histology were much higher for reactor deer compared with non-reactor deer (0.91 versus 0.64), and the same trend was evident for ZN histology (Table 3).

Table 3: Performance characteristics of histological tests for cases of *M. bovis* infection in red deer

Performance	Total deer		Reactors		Non-reactors	
characteristic	HE*	ZN**	HE	ZN	HE	ZN
Sensitivity	0.7895	0.3317	0.8438	0.3442	0.7581	0.3245
Specificity	0.6377	0.8031	0.6286	0.7188	0.6327	0.8123
Positive PV***	0.7233	0.6847	0 9122	0.8548	0.6383	0 6099
Suspicious PV****	0.3509	-	0.6875	-	0.2959	-

* Haemotoxylin and eosin-stained tissue sections

** Acid-fast smears

*** Positive predictive value (proportion of cases positive on histology that were positive on culture)

**** Predictive value for lesions suspicious on HE histology

Stratification of data for animal, environment, and diagnostic laboratory effects revealed wide ranges in PPV histology values. As expected, higher PPVs were evident where there were likely to be higher prevalences of *M. bovis* infection in particular sub-populations in which gross lesions were detected at post mortem inspection. PPVs for HE histology for selected categories of slaughtered deer (Table 4) were highest for gross lesions in animals originating from endemic areas (0.90), animals from movement control herds (0.91), and animals greater than three years of age (0.79). PPVs for ZN histology for gross lesions in the same categories of slaughtered deer were similar. "Suspicious" PVs for HE histology were considerably lower.

Logit analysis indicated that the inclusion (or exclusion) of all animal and environmental parameters had marked effects on the sensitivities and specificities of both HE and ZN histology, and the possibility of confounding presented some difficulties in interpretation of PPVs (unpublished data). Notwithstanding this, the PPVs for screening tests for some categories of slaughtered red deer were very high eg. reactor animals from endemic areas with typical gross pathology and typical HE histopathology had a PPV of 0.97, and the same category of animals with suspicious HE histopathology had a PPV of 0.90. Reactor deer from endemic areas with typical gross pathology had a PPV of 0.93, irrespective of laboratory testing, and overall reactor deer with typical gross pathology had a PPV of 0.85.

Table 4: Predictive values of screening tests for *M. bovis* infection in some specific categories of slaughtered red deer

Category	Positive PV*		Suspicious PV **	
	HE	ZN	HE	ZN
Endemic origin	0.9009	0.9333	0.7250	-
Fringe origin	0.7551	0.7200	0.2778	-
Non-endemic origin	0.5368	0.4796	0.1270	-
Movement control herd	0.9125	0.9020	0.7195	-
Accredited or free herd	0.5114	0.4194	0.1429	-
>3 years of age	0.7882	0.7561	0.4444	-
2-3 years of age	0.6759	0.6038	0.1800	-
1 year of age	0.5682	0.5000	0.1515	-
Typical gross lesions	0.7707	0.7400	0.4524	-
Equivocal gross lesions	0.5435	0.5306	0.2222	-

* Predictive value (proportion of cases positive on histology that were positive on culture)

** Predictive value for lesions suspicious on HE histology

Modelling of performance characteristic data using @Risk showed that with both HE and ZN histology there was a marked and steady increase in PPV with increasing prevalence of *M. bovis* infection in the gross lesions detected at post mortem inspection (Figures 1 and 2). Confidence limits for ZN histology were much wider than for HE histology. The association between estimated apparent prevalence (ie. test prevalence) and true prevalence of *M. bovis* for HE histology and ZN histology is shown in Figures 3 and 4.

Discussion

This slaughterhouse surveillance database represents the first comprehensive accumulation of data on post mortem inspection findings with respect to *M. bovis* infection in farmed red deer; a disease problem the extent of which appears to be unique to New Zealand. The problem is not primarily confined to deer that are reactors or which originate from endemic areas; the majority of cases with gross lesions attributable to *M. bovis* that were identified over the three year period of the investigation were non-reactors, and almost half were from fringe or non-endemic areas of origin. This illustrates the central role of slaughterhouse surveillance in any animal health control programme, and the need for quantitative data on the performance of all test systems when making policy and regulatory decisions.

The anatomical distribution of lesions in each animal that were attributable to *M. bovis* was dominated by single lesions. More than half of the lesions were found in the retropharyngeal lymph nodes, one-fifth were found in the ileo-jejunal lymph nodes, and approximately one tenth were found in each of the ileo-caecal, bronchial, and mediastinal lymph node sites. This distribution provides an interesting comparison with the distribution in cattle, where a marked predominance of gross lesions in the thoracic cavity is almost always reported. The cervine anatomical distributions raise the question as to whether the route of infection and/or the pathogenesis of *M. bovis* infection in farmed red deer is different to that in cattle.

When lesions according to primary complex involvement in individual deer were considered, more than 90% of deer had involvement of one or more primary complex sites, and where lesions were confined to one primary complex in an individual animal, lesions in the head again dominated the statistics. This data indicates that current gross post mortem inspection of farmed red deer is targeted at the correct sites for detecting tuberculous lesions, and it is reasonable to assume that detailed examination of each primary complex site by multiple incision should have a good

probability of detecting any gross lesions present. However, the distribution of lesions in primary complexes as described here has implications for future routine inspection of feral red deer in New Zealand, where currently the head and the gastrointestinal tract are not required to be presented for post mortem meat inspection.

With more than 90% of tuberculous deer having gross lesions in one or more of the primary complex sites, current inspection procedures focusing on these sites serves both animal health surveillance and public health needs. However, this study has identified the importance of the mesenteric lymph nodes as a site for tuberculous lesions in red deer and this suggests that these tissues should be routinely incised in *all* deer. This is not a regulatory requirement unless there is a suspicion of tuberculosis, but appears especially important given the high proportion of *M. bovis* cases that are currently found in non-reactor farmed deer in New Zealand.

Gross post mortem inspection for tuberculous lesions as carried out in a commercial slaughterhouse environment will never approach 100% sensitivity. Corner and others (1990) estimate that a reasonable range of inspection procedures may detect only 50% of actual lesions in "high-risk" reactor cattle and any such non-detection rate has it's greatest impact in animals with single lesions located outside the primary complex sites. The overall prevalence of gross pathology typical of tuberculosis in reactor deer in this study was 20.1%, and this represented a prevalence of *M. bovis* infection of 8.6%. If detailed post mortem inspection by fine multiple incision was applied to all possible tissue sites, the work of Corner and others (1990) suggests that the true prevalence of *M. bovis* infection in the cervine reactor population would be somewhat higher. By extension, the high proportion of all tuberculous deer identified by routine inspection of non-reactors suggests that this sub-population would be an equivalent source of undetected cases.

Current regulatory requirements for *routine* inspection of cervine tissues other that those constituting the primary complexes are different than for cattle, are based on arbitrary decisions, and may not represent the best allocation of inspection resources for public health purposes under New Zealand conditions. A detailed analysis of all combinations of anatomical sites in red deer at which lesions attributable to *M. bovis* are found is not developed here, but this will provide more precise information on the risk-based performance of different ranges of inspection procedures as a screening test. It is clear that a single *M. bovis* lesion in a peripheral tissue site is rare in farmed red deer, and future alterations in post mortem inspection procedures for public health purposes, based on a risk analysis approach, may result. However, any such alterations could have a different impact on screening for animal health control purposes eg. if rare anatomical distributions were concentrated in sub-populations of particular interest for surveillance reasons, and such considerations are important in development of future policy.

It is noteworthy from this study that the proportion of *M. bovis* cases from reactor compared with non-reactor deer with gross pathology typical of tuberculosis was very similar (34.4% and 34.0% respectively). This is very different to the situation in cattle, where the proportion *M. bovis* cases from reactors with lesions typical of tuberculosis may be up to five times higher than that for non-reactor cattle (unpublished data). It is obvious that over the last three years, New Zealand deer farmers have been forwarding large numbers of untested red deer from infected herds for slaughter, and routine post mortem inspection in slaughterhouses is functioning from a national perspective as an essential animal health surveillance tool.

Significant associations between animal / environmental factors and differences in the anatomical distribution of lesions were found for some variables, including sex, age and reactor status, and these will be further investigated. Reactor and non-reactor deer did not appear to represent markedly different epidemiological groups with respect to overall distribution of gross lesions but controlling for all animal / environmental factors by log linear analysis and logistic regression indicated a positive association between primary complex lesions and reactors, compared with non-reactors. Head primary complex lesions were significantly associated with accompanying abdominal primary complex lesions compared with accompanying thoracic lesions, and this may reflect a particular pathogenesis of infection in red deer. Such a pathogenesis may also have contributed to the significant negative association between head lesions and lesions at sites outside of the primary complexes.

The efficiency and cost-effectiveness of post mortem inspection for both animal health and public health purposes is heavily dependent on the judgements made with respect to the outcomes of screening tests. It was evident from this study that gross lesions in the general slaughter population that were typical of tuberculosis (PPV of 0.77) were not a sufficiently accurate general indicator of *M. bovis* infection. However, recourse to animal / environmental information to identify specific sub-populations so as to improve this probability is possible eg. red deer that are reactors, originate in an endemic area, and have gross pathology typical of tuberculosis have a very high PPV for *M. bovis* infection (0.93). Unfortunately, this type of animal / environmental information is not currently available on a consistent basis at the time of slaughter.

Confirmation of gross diagnoses therefore generally depends on laboratory tests, and in this respect ZN histology was shown to be of little value in farmed red deer. In only one of 412 positive ZN histology cases was there a corresponding negative HE histology result (not a "case") and the sensitivity of ZN histology was low. This suggests that routine use of this screening test should be re-evaluated.

HE histology was shown to be a valuable screening test, especially for reactor animals. The PPV for histopathology typical of tuberculosis in this general class of slaughtered livestock was 0.91, indicating that a judgement of *M. bovis* infection based on this result would be correct in nine of

ten instances. However, the PPV for the non-reactor class was considerably lower and a judgement of *M. bovis* infection based on histopathology typical of tuberculosis would be correct in only six of ten cases. If the outcome of HE histology was suspicious, PPVs were much lower for non-reactor deer and judgements based on histology alone would clearly be inappropriate.

PPVs for some specific categories of slaughtered deer further demonstrated the usefulness of HE histology as a screening test under current New Zealand conditions, but only for some sub-populations. Deer originating from endemic areas and deer from movement control herds had PPVs for HE histopathology typical of tuberculosis that were higher than 0.9, but PPVs for deer originating from non-endemic areas or from accredited/free herds were approximately 0.5. It should be noted that identification of these particular sub-populations of slaughtered deer is not routinely available at the slaughterhouse at the time when judgements on the outcomes of HE histology for public health purposes (and decisions on any further actions) have to be made.

Post mortem inspection systems are primarily put in place to provide public health assurances and certification, and judgements on the outcomes of screening tests for public health purposes are inevitably based on a number of factors additional to food safety considerations. These will include consideration of:

(i) the *overall* performance of the meat inspection procedures in place, and overall risk-based allocation of meat inspection resources;
(ii) information that is *routinely* available at the time of post mortem inspection eg. reactor/non-reactor;
(iii) information on animal / environmental factors that *may* be available via additional information pathways;
(iv) the practical outcome of judgements in terms of handling and storing suspect product;
(v) the loss in economic value of product according to different judgements taken on the outcomes of different screening tests;
(vi) the cost of further diagnostic tests eg. culture, to provide further information for judgement purposes.

Although public health judgements on suspect tuberculous cases generally serve animal health needs, targeted disease control programmes may require more precise information to service specific on-farm strategies for defined sub-populations eg. it may be much more important to know the precise *M. bovis* status of gross lesions in an untested animal from a free herd in a non-endemic area than for a reactor from a movement control herd in an endemic area. In such instances, public health judgements based on PPVs for outcomes of different screening tests may not adequately serve a targeted disease control programme. Additionally, the sensitivity of the initial gross post mortem screening test may be insufficient to serve the needs of a targeted disease control (or meat hygiene) programme in specific situations.

The need to appropriately confirm gross lesions as being due to *M. bovis* for animal health purposes will require improved information flows between slaughterhouses, laboratories and animal health field offices, and will need to take into account the physical capacity of the national reference laboratory to culture the desired number of samples and the cost-benefit of these cultures. A more extensive and consistent supply of information on individual reactor animals when they are slaughtered would also markedly improve the efficiency and cost-effectiveness of public health judgements on the outcomes of screening tests.

Given the quantitative performance characteristics for different screening tests for *M. bovis* as elaborated in the present study, modelling of animal health and public health needs will allow development of specific decision-making criteria for the outcomes of screening tests that best serve the two, sometimes disparate goals of the post mortem meat inspection system. In particular, the unfocused requests for culture that are currently very common could be eliminated, and this laboratory resource focused where it will have the most benefit. It will also be important to monitor the prevalence of *M. bovis* in both the reactor and non-reactor slaughter population, as PPV values are affected by the true prevalence of the disease of interest. The @Risk simulations carried out in this study demonstrate that when the true prevalence of *M. bovis* infection in a population of gross lesions suspected of being tuberculous is high, PPVs can be very high. This effect is currently seen in specific sub-populations eg. red deer that are reactors, originate in an endemic area, and have gross pathology typical of tuberculosis have a PPV for *M. bovis* infection of 0.93, and this increases to 0.97 if HE histology typical of tuberculosis is found. However, success in the national disease control programme will decrease current prevalences, and likely decrease PPVs. Inclusion of disease control goals with respect to reductions in prevalence of *M. bovis* in the slaughter population will be an important part of modelling decision-making criteria.

Conclusion

This study has utilised an extensive database to develop quantitative parameters for a number of post mortem inspection and diagnostic activities as they relate to *M. bovis* infection in farmed red deer. The anatomical distribution of lesions and the performance characteristics of screening tests have been precisely defined, and it is clear that *M. bovis* infection in this species represents a unique expression of this disease. Review of regulations and policy for both public health and animal health programmes is needed some areas, and more detailed analysis is required in some cases to define appropriate changes. The generally poor performance of current screening tests in deer for determining the infective status of individual animals (as verifiable by gross pathological examination) and the implications of this for the ongoing disease control programme suggests that development of more accurate tests is an urgent research priority.

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