An abattoir study of tuberculosis in a herd of farmed elk

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Abstract

The purpose of this study was to examine the prevalence and distribution of grossly visible lesions of tuberculosis in a herd of 344 North American elk (*Cervus elaphus*) depopulated during a three-month period in 1991. Abattoir inspection detected mycobacterial lesions in 134 (39.8%) of the 337 animals received for slaughter. The prevalence of lesions increased with the age of the animals. Lesions were predominantly suppurative rather than caseous, and mineralization was less evident than in tuberculous lesions in cattle. Lesions occurred predominantly in lymph nodes, and lungs were the only organs in which mycobacterial lesions were found. The distribution of lesions suggested that aerosol transmission was the most significant means of spread of the disease within the herd. Giant liver flukes (*Fascioloides magna*) were observed in approximately 80% of the adult elk.

Résumé

Étude sur la tuberculose au sein d'élans

Le but de cette étude était d'évaluer la prévalence et la distribution des lésions macroscopiques de tuberculose dans un troupeau de 344 élans d'Amérique (*Cervus elaphus*) dépeuplé sur une période de 3 mois en 1991. À l'abattoir, l'examen a révélé des lésions présumées causées par des mycobactéries chez 134 (39,8 %) des 337 animaux reçus pour abattage. La prévalence des lésions augmentait avec l'âge de l'animal. Les lésions étaient suppuratives d'une manière prédominante et la minéralisation était moins évidente que dans les lésions de tuberculose bovine. Les lésions se localisaient surtout dans les noeuds lymphatiques. Les poumons étaient le seul organe présentant des lésions présumées de mycobactéries. La distribution des lésions suggère que la transmission de l'infection au sein du troupeau s'est faite principalement par aérosol. Des douves géantes (*Fascioloides magna*) ont été observées chez environ 80% des élans adultes.

(Traduit par Dr Thérèse Lanthier)

Introduction

Cases of *Mycobacterium bovis* infection in free-ranging North American wildlife have been extremely rare, with the exception of bison in and around Wood Buffalo National Park (1,2). However, the disease has been a widely recognized problem in captive wildlife in zoos and animal colonies (3,4), and more recently, in game farms around the world (5–7). As the game farming industry has grown in Canada and elsewhere, so has recognition of the significance, and need for surveillance, of diseases in captive wild ungulate populations, especially *M. bovis* infection in Cervidae (8).

The epidemiology, pathology, and control of tuberculosis in farmed deer, primarily in Europe and New Zealand, has been reviewed (6), but there is limited information on the disease in captive North American elk (*Cervus elaphus*) managed under North American game farming conditions (9–12). In the early 1980s, an extensive outbreak of tuberculosis in US game farms was initiated by the introduction of tuberculous elk from a zoo onto a game farm (5,9).

In 1990, tuberculosis occurred in nine herds of farmed elk in Alberta and one herd in Saskatchewan. This was the first outbreak of the disease in commercial herds of elk in Canada. The purpose of this opportunistic study was to examine, under abattoir conditions, the prevalence and distribution of grossly visible lesions of tuberculosis in a herd of elk depopulated within a short period of time.

Materials and methods

Case history and epidemiology

In the fall of 1990, mid-cervical and comparative cervical skin tests detected several tuberculin-reactive animals in a herd of 344 elk in southern Alberta. The herd was placed under quarantine. Three of the elk that reacted to tuberculin were killed and necropsied in November 1990; they were found to have lesions indicative of mycobacteriosis. *Mycobacterium bovis* was subsequently isolated from these lesions.

Review of farm records indicated that the Canadian herd had originated from animals imported from the United States in the spring and summer of 1987. This US source was later confirmed to be infected with *M. bovis* on traceback from the Canadian outbreak. Since 1987, only 29 other elk had been added to the Canadian herd. These came from five game farms in Alberta, none of which were found to be infected, based on subsequent traceback and repeated tuberculin testing of all animals. The herd was isolated from other livestock, and no other livestock in the vicinity of the farm were found to have tuberculosis. The cattle population of Alberta was free of tuberculosis throughout the period that the disease occurred in elk. In December 1987, the herd of elk had been reduced through the sale of every fifth animal that passed through a segregation gate. The purchaser's elk herd, also in Alberta, was later found to be infected with *M. bovis*.

All of this information suggested that the herd had been infected since its inception in 1987, as a result of importation of one or more infected elk from the United States. At the time of depopulation, 103 elk in the herd had ear tags issued by the US Department of Agriculture.

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Table 1. Comparison of the gross and histological lesions detected in captive elk (*Cervus elaphus*) from herds bacteriologically confirmed to be infected with *Mycobacterium bovis*

	Histological lesions compatible with a diagnosis of mycobacteriosis	Histological lesions not compatible with a diagnosis of mycobacteriosis
Gross lesions suggestive of mycobacteriosis	27	5
No gross lesions or gross lesions not considered mycobacteriosis	3	89

Sixty-one calves were produced in 1988. Fifty-eight were sold out of the herd prior to March 1989, and all of these were subsequently slaughtered. There was no gross evidence of tuberculosis in 47 of these elk and postmortem results were unavailable for the other 11 elk. Of the three calves that remained in the herd, one died with no postmortem examination, and two were slaughtered during the depopulation in 1991.

Eighty-five calves were born in 1989. Fifty-five were sold out of the herd in October and November 1989, when they were five to six months of age, and all were subsequently slaughtered. Four of 43 of these elk had gross lesions of tuberculosis and postmortem results were unavailable for the other 12 elk. Of the 30 elk born in 1989 that remained on the farm, one died before quarantine was imposed on the herd and did not have lesions compatible with tuberculosis; one was killed and necropsied in November 1990 for confirmation of results of the tuberculin tests; one died while the herd was in quarantine and had gross lesions of tuberculosis; and 27 were slaughtered at the abattoir during depopulation of the herd.

Ninety calves were born in 1990 and kept on the farm. Twelve of these were sold in October 1990 (no postmortem results); two died with abscessation of the jaw but no other recorded lesions; one died after quarantine had been imposed on the herd and had gross lesions of tuberculosis; and 75 were slaughtered at the abattoir during the depopulation of the herd. All 81 calves born in 1991 were slaughtered during the depopulation of the herd, except for one calf that died during loading, which did not have lesions compatible with tuberculosis.

Husbandry

The herd was held on a farm, consisting of 259 ha under fence and with a shed and handling unit. The pasture was divided into 11 areas, and the elk were segregated by sex and age. Stags one year of age and older were held together; breeding stags were removed for the mating season and then returned. Breeding hinds were held together. Replacement hinds were held separately until 18 mo of age and then moved into the breeding enclosure, where they remained with the older hinds. Calves were weaned at the end of August and remained together until one year of age. The yearling stags were introduced into the stag herd when they were 12–14 mo of age, after velveting was completed.

Water was provided in automatic watering bowls, shared between pens. Pasture grass was supplemented with hay in feed bunks, commercial alfalfa pellets fed on the ground, and some grain in raised bunks. Fence-line contact varied; it rarely occurred between groups of stags and hinds, because the calves and yearling hinds were usually penned between these two groups.

Slaughter

The herd was depopulated between September 18 and December 5, 1991. The abattoir received a total of 337 animals, which were slaughtered and inspected in groups of approximately 30 per day under the supervision of the same veterinarian. All ear tag numbers and codes were recorded, and the ear tags were removed at slaughter and retained on a wire loop in the order in which the animals were killed. Each birth year cohort was identified by the color of the numbered plastic ear tag used for farm management, and this was verified by farm and government records, and by carcass weights of young animals. The sex recorded for each animal was cross-matched with farm and government records. Most elk had both Canadian and Alberta ear tags, 103 also had US federal ear tags, and some had US state ear tags.

Postmortem examination of each animal was conducted according to the guidelines for the inspection of cattle under the meat inspection regulations of the Government of Canada (13). All major viscera were examined and palpated, and the lungs, liver, spleen, and kidneys were incised. Time and facilities were not available to examine the conchal or paranasal sinuses, or the brain. The alimentary tract was not opened because of the hygienic requirements of the abattoir.

The lymphoid structures systematically exposed and incised included the palatine tonsils and the parotid, submandibular, retropharyngeal, mediastinal, bronchial, mesenteric, portal, internal iliac, suprascapular, and prefemoral lymph nodes. Lymph node abscesses less than 5.0 cm in diameter were incised, but larger ones were not opened in order to minimize environmental contami-

Table 2. Distribution of mycobacterial lesions, according to age and sex, in a herd of captive elk (*Cervus elaphus*) bacteriologically confirmed to be infected with *Mycobacterium bovis*, where the disease was introduced in 1987 and the herd depopulated in 1991

	1991 cohort (calves)	1990 cohort (yearlings)		1989 cohort (2-yr-old)		Pre–1989 (≥ 3-yr-old)		Total
		Hinds	Stags	Hinds	Stags	Hinds	Stags	
No gross lesions	75	44	15	2	0	33	34	203
Head only	1	0	1	2	0	18	3	25
Thorax only	0	1	0	5	2	15	2	25
Abdomen only	1	0	0	3	1	11	0	16
Head and thorax	0	0	5	2	0	9	1	17
Head and abdomen	0	0	1	1	0	5	0	7
Thorax and abdomen	2	0	2	2	0	10	2	18
Head, thorax and abdomen	1	2	3	2	3	10	0	21
Body and cavities	0	0	1	1	1	2	0	5
Total	80	47	28	20	7	113	42	337

nation and the risk for workers in the abattoir. The location and characteristics of each lesion were immediately recorded.

Sets of tissues were collected from several of these elk, and from elk in other depopulated herds, so that the accuracy of gross postmortem inspection could be measured against histological findings. Tissues from 124 elk were submitted for laboratory evaluation; 32 with gross lesions suggestive of mycobacteriosis and 92 with either no lesions or lesions thought to be due to other causes. A small portion of each lymph node was placed in 10% neutral buffered formalin in one of four containers labelled head, thorax, abdomen, and carcass. Grossly visible lesions were submitted in separate labelled containers. Bacteriological examinations were conducted on some of the remaining portions of fresh tissues, which were grouped in the same categories as the histological samples. However, bacterial culture had to be limited because of expense and, therefore, histology was relied upon for confirmation of mycobacteriosis.

The criteria for a presumptive gross diagnosis of tuberculosis were the presence of one or more abscesses or granulomas (with or without mineralization) in retropharyngeal, mediastinal, bronchial, or mesenteric lymph nodes, or lung, in an elk from a herd bacteriologically confirmed to be infected with *M. bovis*. Cases of cranioventral (lobar) bronchopneumonia with no grossly visible abscesses or granulomas in bronchial, mediastinal, or other lymph nodes were recorded, but not as tuberculosis. Exclusion of the latter cases from the pre-

sumptive gross diagnosis of tuberculosis was based on knowledge of the disease in cattle, where pulmonary lesions are usually focal and have a dorsocaudal distribution (14,15). The criteria for a presumptive histological diagnosis of tuberculosis were the presence of acid-fast bacilli within foci of typical granulomatous inflammation in the tissue of an elk from a herd bacteriologically confirmed to be infected with *M. bovis*. Statistical comparisons of frequency of occurrence of lesions among different groups of animals or different anatomical locations were done using the Yates' corrected chi-square test.

Results

On antemortem inspection, none of the elk were debilitated or emaciated. On postmortem examination, they were in good bodily condition with minimal bruising. Generalized lymphoid hypertrophy was common in many of the elk, regardless of the presence or absence of lesions, and was histologically identified as lymphoid hyperplasia. There were no fistulae between the surface of the skin and any lesions present in the animals. Approximately 80% of the adult elk had hepatic lesions caused by giant liver flukes (*Fascioloides magna*), and some had microscopic eosinophilic tracts in their lungs caused by fluke migration.

Lymph node lesions predominated in most cases of mycobacteriosis, and most of these lesions were suppurative in character. On cut surface, 126 (48.1%) of 262 lymph node abscesses lacked gross evidence of

mineralization. The retropharyngeal lymph nodes were the most consistently affected lymph nodes of the head. Abdominal lesions were confined to the mesenteric lymph nodes. Visceral lesions compatible with a diagnosis of mycobacteriosis were observed in 76 elk and were limited to the lungs and pleura. Gross lesions were not seen in the mucosa of the pharynx, with the exception of an abscessed medial retropharyngeal lymph node draining into the pharynx seen in one animal. Small, pale lesions seen on cross-section of the palatine tonsils in several elk were histologically identified as foreign body reactions. No lesions were found in the urinary system, reproductive tract, or mammary glands of any elk.

Using histological results as a baseline for comparison, gross postmortem inspection had a sensitivity of 90% and a specificity of 95% in detecting mycobacteriosis in these elk under these abattoir conditions (Table 1). There were three false-negative gross diagnoses. Lesions in two elk, described as "bronchopneumonia probably of pyogenic bacterial origin," were histologically characterized as granulomatous pneumonia with acid-fast bacilli. These two cases were noteworthy because the thoracic lymph nodes appeared normal grossly but did contain microscopic granulomas with acid-fast bacilli. In four other cases categorized as "bronchopneumonia probably of pyogenic bacterial origin," histological examination concurred that these lesions were not mycobacteriosis. The third false-negative diagnosis was a liver abscess which, histologically, contained a single acid-fast bacillus, but an inflammatory response "atypical of *M. bovis* infection." Although this case did not precisely fit our histological criteria, we included it among the cases of tuberculosis because of the presence of an acid-fast bacillus.

The five false-positive gross diagnoses included palpable lung lesions in four elk that were histologically described as eosinophilic granulomas with fibrosis, probably caused by migrating flukes, and a focal lung lesion in one elk that was histologically described as mycotic pneumonia.

The distribution of tuberculous lesions in the elk is summarized according to age and sex in Table 2. These data are based on gross findings, supported by histology where available. In total, 134 (39.8%) of the 337 elk had grossly visible lesions compatible with a diagnosis of mycobacteriosis. The overall difference in prevalence of lesions in hinds (101/180) and stags (28/77) was not significant. There were significant (chi-square, p<0.05) increases in the prevalence of lesions with age between calves (5/80) and yearlings (16/75), and between yearlings and two year olds (25/27). The apparent decrease in prevalence between two-year-old elk and those that were three years old and over (88/155) was not statistically significant. There was a significantly higher prevalence (chi-square, p < 0.005) of lesions in yearling stags (13/28) than in yearling hinds (3/47), while in the group of elk three years old and over, the prevalence of lesions was higher (chi-square, p < 0.005) in hinds (80/113) than in stags (8/42).

There was no significant predilection for lesions to occur in one single anatomical region (head, thorax, or abdomen) over another, either within age groups or overall. Only in the yearling cohort was it significantly more common for lesions to occur in multiple (14 of 16 affected elk) rather than single anatomical regions (chi-square, p < 0.05). Examination of only the lymph nodes of the head and thorax would have detected 118 (88.1%) of the 134 elk with lesions.

Discussion

As is typical of tuberculosis in well-managed livestock, the elk that arrived at the abattoir were clinically normal on visual inspection, despite the high prevalence of infection. This was true even for those elk with widely distributed, extensive lymphoid and pulmonary lesions, and it illustrated the difficulty of making a diagnosis of tuberculosis, and of determining the extent of the disease, in a population of animals based only on inspection of living animals.

The suppurative lymphoid lesions often seen with little or no mineralization in these elk differed from the caseous and mineralized lesions generally seen in cattle with tuberculosis. Because the lesions often looked like abscesses caused by common pyogenic bacteria, it would be possible to overlook tuberculosis in the differential diagnosis of suppurative lymphadenitis in elk.

Comparison of gross inspection against histological results indicated that, as a means of detecting tuberculosis under these circumstances, gross inspection was highly sensitive and specific. Histology results alone are not the best baseline, because they cannot differentiate species of mycobacteria seen in granulomatous lesions. Bacteriology might have been a better baseline, but the sensitivity of bacterial culture as a definitive test for mycobacteriosis is unknown and, in this instance, was prohibitively expensive. All of the elk in the herd were necropsied under the supervision of one veterinarian (T. Whiting) who had conducted postmortem examinations on over 760 elk during the outbreak of tuberculosis. It was likely that his experience favorably biased the sensitivity and specificity of gross inspection in detecting mycobacterial lesions.

The prevalence of lesions in this herd of farmed elk was high. Hadwen (16) reported tuberculous lesions in only 73 (5.5%) of 1,329 wild elk that shared a 512 km^2 fenced compound with a heavily infected herd of bison. This suggests that increased population density, management factors, or both enhanced transmission of the disease in these farmed elk. Similarly, the 39.8% prevalence of lesions in these elk was higher than values reported in range cattle, but comparable to those reported in housed cattle (3).

The likelihood of an elk developing lesions of tuberculosis increased with duration of exposure to infected herd-mates based on the positive correlation between age and prevalence of lesions, as has been observed in abattoir surveys of infected cattle (17). Comparison of exposure rates and prevalence of lesions among calves, yearling hinds, and two-year-old hinds suggested that the relationship of increasing prevalence with age was not linear. The low prevalence of lesions in the calves, and the absence of lesions in the mammary glands and uterus of the frequently infected breeding hinds, indicated that transplacental and milkborne transmission were not significant factors in the spread of the disease.

It was noted that the yearling hinds had a low prevalence of lesions, comparable to that of calves, while the yearling stags had a significantly higher prevalence of lesions. The only difference in management that might explain this was that the yearling stags were mixed with the adult stags four to six months before yearling hinds were mixed with the breeding hinds. Although the sample size was small, it was also noteworthy that yearlings had a significantly higher prevalence of disseminated lesions than other age cohorts.

The fact that the calves and yearling hinds had the same prevalence of lesions, and that these groups were maintained in adjacent enclosures, suggests that transmission of the disease was not amplified by fence-line contact. We do not know why the prevalence of lesions was significantly higher in hinds than stags in the three-year-old and older animals, but it may simply have been due to the smaller number and lower density of animals in the stag herd.

The number of elk with lesions in some age and sex categories was too small to comment on the distribution of lesions. In cattle with tuberculosis, predilection for lesions in the thoracic lymph nodes, lungs, and pleura has been interpreted as evidence of aerosol infection, while predilection for abdominal viscera and lymph nodes has been interpreted as evidence of oral exposure (3,18). Lesions in the lymph nodes of the head could occur by either route of infection (19). That 81 (60.5%) of 134 elk with lesions had thoracic involvement, including 76 with pulmonary and pleural lesions, suggests that aerosol transmission was most important in the spread of the disease. During the outbreak of bovine tuberculosis in Canadian elk, one veterinarian became positive on Mantoux test and *M. bovis* was isolated from his sputum after he had clinically examined retropharyngeal lesions in an affected elk (20), also suggesting the significance of aerosol transmission.

Sixteen elk had mycobacterial lesions only in mesenteric lymph nodes, which may indicate that oral infection had occurred. Lesions in mesenteric lymph nodes in cattle may arise from swallowing *M. bovis* in their own sputum (21) and small pulmonary lesions can be overlooked during abattoir inspection (22). Oral transmission is much less efficient than aerosol transmission because the infective oral dose of *M. bovis* is several orders of magnitude greater than the infective dose of aerosolized bacteria (23). In experiments where bovine calves were infected orally with *M. bovis* in milk, two developed pulmonary lesions attributed to aspiration, others had either abdominal lesions or no lesions, and only one had lesions confined to the thoracic cavity (19,24). In humans, nearly all cases of infection by *M. tuberculosis* are the result of aerosol transmission, and extrapulmonary manifestations of the disease are the result of hematogenous or lymphatic dissemination of the bacterium from the lung (25).

Acknowledgments

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