The Relationship between the Disclosure of Tuberculous Lesions in Attested Cattle and the Factory, Year, Month and Class of Cattle in Ireland, 2001-02

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Introduction

Every animal slaughtered for the meat export market is examined at the time of slaughter for evidence of disease, including tuberculosis. This process protects the purchaser/consumer of the product and also, given that a large number of animals are slaughtered annually, serves as a surveillance tool for animal disease control and eradication. Annually, over the past number of years, data have been summarised which describe the frequency of tuberculosis lesions in different classes of cattle across different years (Costello *et al.*, 1998; Lenehan *et al.*, 1999; Byrne, 1999). The risk of lesions by class of animal (with cows having the highest risk) has been observed and, with a number of years of data in hand, trends in lesion risk have been observed. These observations were based on a comparison of the percentage distribution of lesions by class with the percentage distribution of the number of animals slaughtered by class. Based on this approach, cows were deemed to have the highest risk of having a lesion, and also the highest confirmation risk (proportion tuberculosis positive/number submitted). These analyses were "marginal" (or crude) in the sense that only one factor was examined at a time, and, by implication the impact of all factors was ignored. More detailed analyses will require control of the confounding effects of these factors, since when we make comparisons among proportions, risks or rates based on only one feature (say, class of animal), the results can be confounded (distorted, or biased) by the distribution of other factors that influence the frequency of lesions (e.g. perhaps season has an effect and different classes of cattle are marketed at different times of the year). Two techniques can help prevent this confounding. One is a descriptive method known as standardisation, the other is an analytic approach using a regression model. We first describe the basis for standardisation.

Although it may not be apparent, to the casual observer, the overall frequency of disease in a class of animal is a function of the distribution of host and other factors (denoted here as H_i and encompassing year, month, factory and class) and the risk of disease (R_i) in each of the categories representing the combinations of these factors. The distribution (H_i) component is thus N_i /N, the proportion of the study group or population in each of the factor combination categories. The subscript i denotes the confounder level (eg. factory), or confounder combination (eg. month-year). Based on this the crude lesion risk (a measure of prevalence at slaughter) in a class of animal is:

$$Crude\_risk = \sum H_i R_i = R$$

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Since the H_i represents the distribution of the confounding factors, we can use this information to adjust the overall frequency measure for confounders by using a set of H_{stdi} from a standard population. This is called direct standardisation in that we use the standard distribution and multiply it by the observed risks to obtain the adjusted risk. Another approach, that is preferred when the number of cases per stratum is small, is to use a set of R_{stdi} from a standard population. Applying these rates to the observed population structure allows us to estimate the expected number of cases and compare this with the observed number of cases; the ratio of observed to expected gives the standardised morbidity ratio (SMR). SMRs above 1 suggest that animals in that class have an excess of cases, while SMRs below 1 suggest a relative deficit of cases. In either case, the adjusted risk (or SMR) in each class is free of confounding from the factors that are included in the adjustment. Of course we can use the same approach to obtain lesion risks by factory, having adjusted for class of animal and other factors.

The second approach to preventing confounding is through the use of a regression model. Linear models are the most similar approach to the adjustment just described. However linear models assume the risks are normally distributed, whereas in fact they usually are highly skewed. Thus this prevents the optimal use of this approach and this also is, in fact, a drawback to using the standardisation approach just described. Two other regression approaches are useful, one is the logistic model which treats the risk data as binomial data; the other approach is Poisson regression which better suits data such as the lesion data where the frequency of outcome is low. In these methods, control of confounding is achieved by including the factors of interest in the regression model.

Regardless of the method chosen to adjust for confounding, it is important when summarizing the risks that we ascertain that the risks are reasonably consistent across the strata (the combinations of the other factors in the adjustment). If this is not the situation then interaction is said to be present and the standardisation approach "over-simplifies" the situation. In a similar manner the regression model must include the interaction terms or the coefficients obtained from it also are biassed. Thus it is often best to start with a visual assessment of the data to identify possible interaction. The regression approach is somewhat more flexible than standardization as it allows a statistical assessment of interaction.

Data

Suspect lesions are forwarded to the Central Veterinary Research Laboratory for confirmation of tuberculosis status, and the data on these lesions submitted from "clear" cattle in 2001 and 2002 were obtained from that facility. These data describe the class of animal the specimen was obtained from, the date of submission and the factory identification. Data on the number of cattle slaughtered by class and month were obtained from factories that export cattle products for the years 2001 and 2002 from Ms Anne Troy of the Department of Agriculture and Food, Beef Classification, Marketing and Trade, Johnstown Castle, Co. Wexford. These data were merged for all factories that had submitted at least one lesion for verification (a number of factory identifications could not be matched to the production data, or the factories did not submit lesions).

We used indirect adjustment to standardise the risk of having a lesion submitted by class and the risk of having a tuberculous lesion by class. For comparison, we used Poisson regression to compare risks having adjusted class risks for factory, year and month effects. All analyses were performed in STATA©.

Results

Table 1 contains a summary of the data. The greatest number of suspect lesions were submitted from steers, whereas cows had the highest percentage of tuberculosis positive lesions among all lesions submitted (68.63%) and steers the lowest (58.5%). The crude prevalence of lesions submitted was 21.8 per 10,000 and the prevalence of tuberculous lesions was 13.6 per 10,000. Cows had the highest risk of both lesions and of tuberculous lesions, followed by steers, with bulls and heifers with the lowest risks. A visual summary of the risk of having a tuberculous lesion by class is shown in Figure 1.

Figure 1. Risk of tuberculosis by animal class.

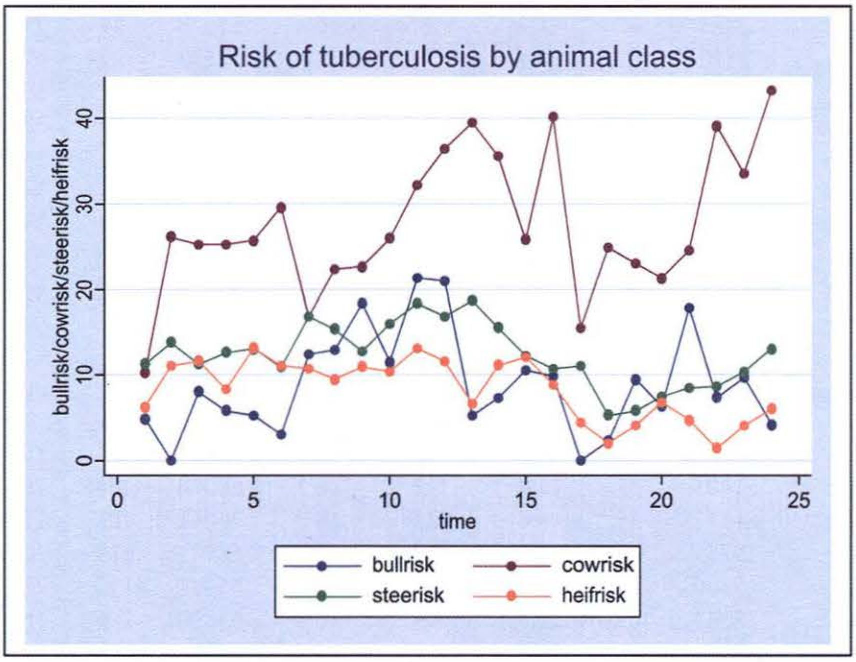

Table 1. Summary data on tuberculosis positive lesions and all lesions by class of cattle in Ireland 2001 – 2002.

		Bulls					Cows			
Year	Month	Number	Total Lesions	Lesion Risk	Tuberculous Lesions	Tb Risk	Number	Total Lesions	Lesion Risk	Tuberculous Lesions
2001	Jan	2269	1	4.4	1	4.4	12574	21	16.7	13
	Feb	2612	0	0.0	0	0.0	19889	69	34.7	51
	Mar	4207	6	14.3	3	7.1	20725	65	31.4	51
	Apr	3910	4	10.2	2	5.1	18187	56	30.8	45
	May	8237	7	8.5	4	4.9	18652	68	36.5	46
	June	7294	6	8.2	2	2.7	14847	65	43.8	42
	July	6284	9	14.3	7	11.1	25349	68	26.8	42
	Aug	5216	10	19.2	6	11.5	32195	121	37.6	70
	Sept	3973	9	22.7	7	17.6	25312	101	39.9	56
	Oct	4464	7	15.7	5	11.2	36268	141	38.9	91
	Nov	5304	14	26.4	11	20.7	38983	164	42.1	121
	Dec	2938	9	30.6	6	20.4	27227	124	45.5	96
2002	Jan	3836	4	10.4	2	5.2	23579	111	47.1	89
	Feb	2742	6	21.9	2	7.3	17083	77	45.1	57
	Mar	2873	4	13.9	3	10.4	11578	34	29.4	28
	Apr	3110	8	25.7	3	9.6	12533	59	47.1	47
	May	6342	2	3.2	0	0.0	14586	28	19.2	21
	June	4394	2	4.6	1	2.3	12774	41	32.1	30
	July	4224	5	11.8	4	9.5	20106	59	29.3	43
	Aug	3220	3	9.3	2	6.2	19614	67	34.2	39
	Sept	2903	8	27.6	5	17.2	20948	74	35.3	47
	Oct	2722	4	14.7	2	7.3	24266	153	63.1	88
	Nov	3110	5	16.1	3	9.6	26917	132	49.0	86
	Dec	2449	3	12.2	1	4.1	17983	98	54.5	72
		Heifers					**Steers**			
Year	Month	Number	Total Lesions	Lesion Risk	Tuberculous Lesions	Tb Risk	Number	Total Lesions	Lesion Risk	Tuberculous Lesions
2001	Jan	20702	20	9.7	12	5.8	53930	97	18.0	56
	Feb	21405	35	16.4	22	10.3	66270	134	20.2	85
	Mar	21111	35	16.6	23	10.9	73048	128	17.5	76
	Apr	15745	25	15.9	12	7.6	58777	119	20.2	67
	May	17390	32	18.4	21	12.1	55441	115	20.7	66
	June	18344	23	12.5	19	10.4	63190	106	16.8	64
	July	15850	32	20.2	16	10.1	46251	123	26.6	71
	Aug	17972	27	15.0	16	8.9	65386	146	22.3	91
	Sept	17826	27	15.1	18	10.1	65264	134	20.5	76
	Oct	21973	26	11.8	21	9.6	70123	157	22.4	104
	Nov	27072	48	17.7	33	12.2	77428	207	26.7	133
	Dec	19273	24	12.5	21	10.9	43082	108	25.1	68
2002	Jan	32155	28	8.7	20	6.2	53625	133	24.8	93
	Feb	21028	27	12.8	22	10.5	48810	107	21.9	70
	Mar	16731	24	14.3	19	11.4	47296	95	20.1	53
	Apr	19182	31	16.2	16	8.3	61371	107	17.4	60
	May	19307	14	7.3	8	4.1	55714	83	14.9	57
	June	15562	9	5.8	3	1.9	39600	47	11.9	20
	July	20379	18	8.8	8	3.9	59139	64	10.8	33
	Aug	18656	19	10.2	12	6.4	56688	88	15.5	40
	Sept	22524	21	9.3	10	4.4	70345	104	14.8	56
	Oct	29076	20	6.9	4	1.4	69567	136	19.5	57
	Nov	36604	24	6.6	14	3.8	58555	118	20.2	57
	Dec	28334	25	8.8	16	5.6	40804	84	20.6	51

The prevalence, by class, varied considerably from month to month over the 2 year time period. There was an apparent cyclicity to lesion prevalence in cows; the peak in 2000 was in June, whereas in 2001 it was in December (Month 1 is January 2001). Because of the different distribution of lesion risk across months within a class we cannot obtain adjusted risks by month using standardisation. However, the differences between classes are sufficiently consistent that adjusting the class risks for the effects of factory, year and month seems reasonable. These are shown in Table 2, based on factories that submitted lesions for examination.

Table 2. Observed and expected numbers of lesions and tuberculosis positive lesions by class of cattle in Ireland, 2001-2002.

Standardised Morbidity Ratios (SMRs) for lesions submitted by class						
	Cases	Crude	Cases		Exact	
Class	Observed	Risk	Expected	SMR	Confidence	Interval
Bull	136	14.6	210.88	0.645	0.541	0.763
Cow	1996	34.9	1296.94	1.539	1.472	1.608
Heifer	614	12.8	1001.44	0.613	0.566	0.664
Steer	2740	20.7	2624.86	1.044	1.005	1.084
Standardised Morbidity Ratios (SMRs) for tuberculous lesions by class						
	Cases	Crude	Cases		Exact	
Class	Observed	Risk	Expected	SMR	Confidence	Interval
Bull	82	8.9	134.14	0.611	0.486	0.759
Cow	1371	23.7	814.35	1.684	1.596	1.775
Heifer	386	8.1	608.58	0.634	0.573	0.701
Steer	1604	12.1	1636.99	0.98	0.932	1.029

From the data in Table 2, based on the SMR, cows have the highest lesion prevalence, followed by steers, bulls and finally steers. Similarly, for tuberculous lesions, cows have the highest risk followed by steers, heifers and finally bulls.

Since the monthly pattern of positive lesion risk differed across year, a Poisson model with interaction of year and month was used to summarise class risks (Table 3).

Table 3. Prevalence ratios of lesion risk and positive tuberculous lesion risk by class, compared to the risk in heifers in Ireland, 2001-02.

Prevalence ratio for lesions by class							
Class	Prevalence Ratio	Coefficient	SE	Z	p>Z	Confidence Interval	
Bull	1.28	0.25	0.10	2.49	0.01	0.05	0.44
Cow	3.04	1.11	0.06	19.71	0.00	1.00	1.22
Steer	1.99	0.69	0.05	13.28	0.00	0.58	0.79
Prevalence ratio for tuberculous lesions by class							
Class	Prevalence Ratio	Coefficient	SE	Z	p>Z	Confidence Interval	
Bull	1.20	0.18	0.13	1.45	0.15	-0.06	0.43
Cow	3.29	1.19	0.07	16.97	0.00	1.05	1.33
Steer	1.83	0.60	0.06	9.30	0.00	0.48	0.73

The class difference in lesions submitted and prevalence of tuberculous lesions is noted with cows>steers>bulls>heifers; cows having over a 3 times increase in risk and steers almost 2X the prevalence in heifers. Interaction was present between year and month so these factors could not be summarised, although the prevalence of lesions in 2002 was higher than in 2001.

Discussion

The crude prevalence of lesions submitted was 21.8 per 10,000 and the prevalence of tuberculous lesions was 13.6 per 10,000. Cows had the highest risk of both lesions and of tuberculous lesions, followed by steers with bulls and heifers with the lowest risks. Both the indirect standardisation and the Poisson regression took the factors, factory, year and month into account but these factors were not strong confounders and the class differences in adjusted risks persisted after adjustment. The class differences noted here, with cows having a high risk of lesions have been reported on before.

We had hoped to produce adjusted prevalences by month across classes to investigate the possible effect of housing and seasonal differences in management. However the inconsistent pattern of prevalence by month in this short time series precluded such a summary. Only cows had a seasonally cyclic pattern but the peaks occurred at different times of the year suggesting that it is not a simple effect of housing or management of this class of cattle.

Both approaches used to summarise the data are easy to use and allow more potential for detailed study of patterns in lesion data. Nonetheless, the findings here for class differences are very similar to those previously reported.

A summary of the tuberculous lesion frequency by factory is included as an Appendix. The variation in prevalence of lesions after controlling for year, month and class effects is large; the difference between the highest and lowest being a factor of 7 times. Reasons for these discrepancies should be sought if detecting lesions at slaughter is to be of national value in the control of bovine tuberculosis.

References

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Appendix 1

A listing of tuberculous lesions and SMRs by factory 2001-02

Factory Number	Cases Observed	Cases Expected	SMR	Confidence	Interval
4	248	290.93	0.852	0.750	0.965
6	146	149.81	0.975	0.823	1.146
8	121	149.6	0.809	0.671	0.966
10	62	113.92	0.544	0.417	0.698
11	330	110.76	2.979	2.667	3.319
12	126	167.31	0.753	0.627	0.897
13	33	111.47	0.296	0.204	0.416
14	53	156.44	0.339	0.254	0.443
16	69	115.87	0.595	0.463	0.754
17	93	53.16	1.749	1.412	2.143
21	135	108.55	1.244	1.043	1.472
22	148	168.77	0.877	0.741	1.030
25	166	118.34	1.403	1.197	1.633
27	671	282.93	2.372	2.196	2.558
29	168	198.25	0.847	0.724	0.986
31	192	146.75	1.308	1.130	1.507
32	48	117.53	0.408	0.301	0.541
33	147	153.84	0.956	0.807	1.123
34	131	157.69	0.831	0.695	0.986
37	39	39.92	0.977	0.695	1.336
43	50	46.76	1.069	0.794	1.410
52	267	29.93	8.92	7.882	10.000