

SHORT REVIEW OF THE LITERATURE EVALUATING THE CONTRIBUTION OF MOVEMENTS OF INFECTED CATTLE TO THE INCIDENCE AND/OR SPREAD OF BOVINE TUBERCULOSIS

INTRODUCTION

Bovine tuberculosis (TB) is an infectious and contagious disease of cattle caused by the bacterium *Mycobacterium bovis* (*M. bovis*). Domestic cattle are the natural host to *M. bovis*, becoming infected when directly exposed to infected, infectious cattle (and their excretions), or other infected, infectious animals (and their excretions).

Therefore, uncontrolled movements of cattle may unwittingly introduce infection in TB-free herds. The movement of infected cattle between epidemiologically separate locations (***translocation***) is probably the main mechanism whereby bovine TB spreads from areas of high TB incidence to areas of low incidence devoid of a wildlife reservoir. Depending on a number of host, environmental and, possibly, *M. bovis* strain-related (molecular) factors, bought-in or imported (“translocated”) infected cattle can amplify the infection within the herds and areas of destination more or less efficiently resulting in ***spread*** of TB within- and between-herds. If this spread into low incidence areas is not checked, it may eventually lead to the establishment of new TB “***hotspots***” in areas previously considered free from TB. Once established, these TB hotspots can be very difficult to eliminate, particularly if the infection spills over into wildlife hosts capable of acting as alternative reservoirs of *M. bovis*.

Control of bovine TB in GB is complicated by the presence of a wildlife reservoir in certain areas of GB, which is geographically static in contrast to the movements of the commercially traded cattle host. In addition to the known reservoir of infection in wildlife, it is believed that movements of tuberculous cattle within and between areas of endemic TB could also be responsible for an unknown (but potentially substantial) proportion of herd breakdowns in those areas.

Several studies have shown that when cattle are introduced to a herd from elsewhere, there is an increased risk of herd breakdowns. This is a short review of the published information relevant to the spread of bovine TB through cattle movements and the value of pre- and post-movement testing as an element of any TB control policy. The majority of the papers cited below stemmed from studies conducted in the British Isles and New Zealand. Given the time and resource constraints, this document is not meant to be a formal, exhaustive scientific review of the veterinary literature, but it shows that there is a body of scientific evidence supporting the need for pre-movement tuberculin testing as a tool for reducing the risk of translocating TB to low incidence areas (and also to assist with the early detection of TB in high incidence areas). No attempt has been made here to assess the extensive body of literature pertaining to the transmission of infection from wildlife to cattle and this summary should not be used to draw comparisons about the relative importance of the various sources of TB herd breakdowns in GB. It is acknowledged that badgers continue to represent a significant source of infection for cattle in large tracks of GB.

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LIST OF SCIENTIFIC REFERENCES AND OTHER PUBLICATIONS ON THE ROLE OF CATTLE MOVEMENTS IN SPREADING BOVINE TB (in alphabetical order)

- Anon. 1991. Bovine Tuberculosis in Badgers. Third Report by the Ministry of Agriculture, Fisheries and Food. London, HMSO.** Of the 1,493 TB breakdowns recorded in the SW of England between 1972 and 1988, 58% were attributed to transmission from badgers and 9% to purchased cattle. Comparable figures for the same sources for the 617 breakdowns reported in the rest of the country over the same period were 6% and 50% respectively.
- Anon. 2005. National bovine tuberculosis pest management strategy: National operational plan for 1 July 2005 – 30 June 2013. Animal Health Board New Zealand. Wellington.** This document sets out a requirement for all cattle 3 months of age and older moving out of (or within) Movement Controlled Areas of New Zealand (i.e. those where TB herd prevalence exceeds 1%) to pass a caudal fold skin test applied in the 60 days prior to the movement (except for cattle going directly to slaughter).
- Barlow, N.D., Kean, J.M., Caldwell, N.P., Ryan, T.J. 1998. Modelling the regional dynamics and management of bovine tuberculosis in New Zealand cattle herds. Preventive Veterinary Medicine 32, 57-75.** The authors presented a computer simulation model for TB transmission between cattle herds in the Waikato region of New Zealand's North Island, which was largely free from wildlife TB reservoirs except for its southern area. The model was used to account for the observed pattern of TB breakdowns and to assess the likely impact of changes in management on the percentage of herds on movement control between 1988 and 1993. The greatest reduction in the percentage of herds on movement control came from yearly testing plus a 50% reduction in infection from wildlife. A further but smaller additional improvement was gained by reducing cattle movements throughout the region by 50%.
- Blissitt, M.J. 2006. The introduction of pre- and post-movement TB testing in Scotland for cattle from high incidence TB areas. Government Veterinary Journal 16(1), 58-64.** This paper gives an account of the rationale, development, introduction and monitoring of the pre- and post-movement tuberculin testing policy in Scotland.
- Carrique-Mas, J.J., Medley, G.F., Green, L.E. 2006. Risk of bovine tuberculosis in British cattle farms restocked after the foot and mouth disease epidemic of 2001. (submitted for publication in the Proceedings of the National Academy of Sciences).** The authors used a binomial logistic regression model on VetNet and CTS data to investigate variables associated with TB herd breakdowns on 2,941 cattle herds re-formed after the 2001 FMD epidemic. The three significant risk factors were: sourcing cattle from herds that were tested for TB at least every 2 years, having a history of TB breakdowns on the restocked farm between 1997 and 2000 and increasing herd size.

Christiansen, K.H., O’Keeffe, J.J., Harrington, B.P., McDonald, E.P., Duggan, M.J., Hayes, M.C., McInerney, P., McSweeney, P.T. 1992. A case-control study of herds which fail the tuberculin test six months after being de-restricted for tuberculosis. In: Selected Papers 1992. Tuberculosis Investigation Unit, University College Dublin, pp 45-48. This study found that herds in Ireland which purchased cattle between the clearance test and the six-month check test were twice as likely to fail this test than herds which did not purchase animals.

Collins, J.D. 2006. Tuberculosis in cattle: strategic planning for the future. Veterinary Microbiology 112, 369-381. The author (an Irish academic) advocates the use of pre- and post-movement tuberculin testing (voluntary or otherwise) for movements of cattle out of herds in known areas of high TB prevalence as a basic principle of preventive medicine and cattle herd health.

Denny, G.O., Wilesmith, J.M. 1999. Bovine tuberculosis in Northern Ireland: a case-control study of herd risk factors. Veterinary Record 144, 305-310. Although herds with reactors in purchased cattle were deliberately excluded from the study, the paper cites a previous unpublished analysis by Denny that suggested that purchased cattle probably accounted for approximately 15 to 20% of herd breakdowns in the province. They also state that, according to DARDNI veterinarians, purchased cattle were implicated as sources of 23% of all TB breakdowns in Northern Ireland in 1996.

Gilbert, M., Mitchell, A, Bourn, D., Mawdsley, J., Clifton-Hadley, R., Wint, W. 2005. Cattle movements and bovine tuberculosis in Great Britain. Nature 435:491-496. The Defra-funded analysis described in this paper showed that cattle movements between herds are major predictors of bovine TB distribution in GB, especially from locations with a history of TB and particularly to areas of GB without a history of TB. The paper pointed out, however, that despite the demonstrated association of cattle movements with TB, there are areas where large numbers of cattle are imported and TB appears but does not persist. The study was not designed to assess the role of infected badgers as a risk factor for TB in cattle and, therefore, it did not negate or support the involvement of badgers in TB transmission to cattle.

Gopal, R., Goodchild, A., Hewinson, G., de la Rúa-Domenech, R., Clifton-Hadley, R. 2006. Introduction of bovine tuberculosis to north-east England by bought-in cattle. Veterinary Record 159, 265-271. A detailed investigation into the 31 confirmed TB breakdowns detected between January 2002 and June 2004 in the Northeast of England (old counties of North, South and West Yorkshire, Northumberland, Durham, Tyne and Wear and Cleveland). The affected herds were all in 4-yearly tested parishes at the time of their breakdowns. Using CTS, VetNet and *M. bovis* typing data, the authors identified purchased cattle (mainly from Wales and endemic TB areas of England) as the most likely source of infection in all but one of the breakdowns. Three breakdowns were traced to cattle imported from Ireland. Some evidence of within-herd spread was found in five herds. In 11 of the breakdowns, the animals that became reactors had originally moved off their most likely source holdings when they were one year old

or younger (10, 12, 13, 14, 15, 20, 261, 299, 400, 400 and 410 days). Such detailed information was not available in another 12 breakdowns, although it was possible to establish that in 7 of those 12 breakdowns the moved animals were less than one year old when disclosed as reactors at the destination herds. This multiple case study provided a concrete example of the potential for young cattle to carry infection and cause TB breakdowns when moved between herds.

- Goodchild, A.V., Clifton-Hadley, R.S. 2001. Cattle-to-cattle transmission of *Mycobacterium bovis*. Tuberculosis 81(1/2), 23-41.** A comprehensive review of the role of cattle-to-cattle transmission in the spread of TB between and within herds. The authors reviewed the various reports on the attribution of sources of infection of confirmed TB incidents in GB (1970s and 1980s) and Ireland (1980s and early 1990s). They also provided a summary of several experiments carried out to show the effects of transmission of *M. bovis* between cattle by housing disease-free in contact cattle with field reactors and intranasally inoculated calves over different periods and under different housing conditions.
- Griffin, J.M. 1992. Analysis of epidemiology reports on outbreaks of tuberculosis involving 504 herds in 22 counties. In: Selected Papers 1992, Tuberculosis Investigation Unit, University College Dublin, pp. 28-32.** Revealed that 7% of 504 non-randomly selected TB breakdowns investigated in Ireland between August 1990 and the end of 1991 were likely to have been caused by purchased cattle. The mean number of reactors in those breakdowns was 3.3 compared to 8.1 in breakdowns of wildlife origin.
- Griffin, J. M., Haahes, T., Lynch, K. 1992. The role of farm management practices and environmental factors in chronic tuberculosis. Irish Veterinary Journal 45, 120-122.** The authors calculated retrospectively that in Ireland, 7-15% of TB breakdowns were due to movements of infected cattle.
- Griffin, J. M., Haahes, T. 1992. Analysis of epidemiology reports on 3,975 herd breakdowns in ten DVO regions during 1987-90. Irish Veterinary Journal 45, 126.** Identified the main causes of infection as lateral spread (25%), residual cattle infection (14%), wildlife (14%) and purchased cattle (11%), with 35% of breakdowns of obscure origin.
- Griffin, J.M. 1993. The role of bought-in cattle in herd breakdowns due to tuberculosis in part of County Cavan during 1989. Irish Veterinary Journal 46, 143-148.** The author concluded that 15% of TB breakdowns in County Cavan (Ireland) were due to the purchase of *M. bovis*-infected cattle. A relatively low incidence of infection in homebred cattle was detected in six of 12 breakdowns attributed to purchased infection.
- Griffin, J.M., Dolan, L.A. 1995. The role of cattle-to-cattle transmission of *Mycobacterium bovis* in the epidemiology of tuberculosis in cattle in the Republic of Ireland: A review. Irish Veterinary Journal 48, 228-234.** In this review the authors concluded that infected cattle can shed *M. bovis* at various stages of the disease, but many other factors determine whether in-contact cattle

become infected. On the basis of the scientific evidence available at the time, the authors concluded that cattle-to-cattle transmission of *M. bovis* was no longer the primary source of new TB breakdowns in Ireland.

Griffin, J.M., Martin, S.W., Thorburn, M.A., Eves, J.A., Hammond, R.F. 1996. A case-control study on the association of selected risk factors with the occurrence of bovine tuberculosis in the Republic of Ireland. Preventive Veterinary Medicine 27, 217-229. A retrospective, case-control study on selected risk factors associated with the occurrence of bovine TB on beef and store herds in East Offaly County. There was little indication that purchase of cattle was a major risk factor for TB. Purchased cattle were less likely to be deemed tuberculin reactors than cattle present in the herd at the previous herd test. However, herds in this study were selected according to their TB status in 1988, i.e. at a time when all cattle in Ireland were required to pass a tuberculin test within 60 days prior to their sale, thus reducing the possibility of buying in infected cattle (this pre-movement testing requirement was abandoned in Ireland in 1996).

Haehsy, T., O'Keefe, J.J., Collins, J.D. 1996. The role of pre-movement testing in the identification of tuberculin reactor cattle. In: Selected Papers 1996, Tuberculosis Investigation Unit, University College Dublin, pp. 45-49. Examined the benefits (but not the costs) of pre-movement testing on the rate of disclosure of TB in infected herds in Ireland.

Johnston, W., Gettingby, G., Cox, D., Donnelly, C., Bourne, J., Clifton-Hadley, R., Le Fevre, A., McInerney, J., Mitchell, A., Morrison, W., Woodroffe, R., 2005. Herd-level risk factors associated with tuberculosis breakdowns among cattle herds in England before the 2001 foot-and-mouth disease epidemic. Biology Letters 1, 53-56. This paper describes a case-control study of the factors associated with the risk of TB breakdowns in three RBCT areas of southwest England active before the 2001 FMD epidemic (TB99 study). The factors most significantly associated with an increased TB risk were the movement of cattle onto the farm from markets or farm sales, operating a farm over multiple premises and the use of covered yards or other cattle housing types.

Marangon, S., Martini, M., Dalla Pozza, M., Neto, F. 1998. A case-control study on bovine tuberculosis in the Veneto Region (Italy). Preventive Veterinary Medicine 34, 87-95. Identified bought-in cattle as one of the main risk factors associated with the occurrence of TB herd breakdowns in Northeast Italy and concluded that where a region is importing large numbers of cattle from infected herds or geographical areas, a sustained incidence of TB can be maintained in an area without a wildlife reservoir.

McIlroy, S.G., Neill, S.D., McCracken, R.M. 1986. Pulmonary lesions and Mycobacterium bovis excretion from the respiratory tract of tuberculin reacting cattle. Veterinary Record 118, 718-721. Based on the findings from his study, the authors concluded that cattle were the major source of TB in Northern

Ireland at the time, with infection derived from purchased cattle accounting for approximately 30% of breakdowns (spread from an infected contiguous herd accounted for 40%).

Menzies, F.D., Neill, S.D. Cattle-to-cattle transmission of bovine tuberculosis.

Veterinary Journal 160, 92-106. Explored the role and factors influencing cattle-to-cattle transmission of *M. bovis* and stressed the difficulties in quantifying the relative frequency of the various causes of herd breakdowns accurately.

Mitchell, A., Bourn, D., Mawdsley, J., Wint, W., Clifton-Hadley, R., Gilbert, M. 2005.

Characteristics of cattle movements in Britain – an analysis of records from the Cattle Tracing System. Animal Science 80, 265-273. Presents an analysis of the main temporal and spatial characteristics of cattle movements in GB for the period 2001-2003, based on the CTS database. There were several hundred thousand cattle movements from herds in the West of England and in Wales each year, the majority of which remained within those regions (43% of movements were over less than 20 km). Although a substantial number of long-range movements took place, the implication is that, in addition to the risk of transmission from badgers, there is also a real and increased risk of moving infected cattle to other premises within areas of high TB incidence. See also Mitchell (2006), Government Veterinary Journal 16(1), 46-52.

Munroe, F.A., Dohoo, I.R., McNab, W.B., Spangler, L. 1999. Risk factors for the between-herd spread of *Mycobacterium bovis* in Canadian cattle and cervids between 1985 and 1994. Preventive Veterinary Medicine 41, 119-133.

This retrospective quantitative study of the spread of *M. bovis* infection between Canadian cattle herds indicated that herds that had received animals from a reactor herd were at the highest risk of becoming, in turn, a reactor herd.

Neill, S.D., Pollock, J.M., Bryson, D.B., Hanna, J. 1994. Pathogenesis of *Mycobacterium bovis* infection in cattle. Veterinary Microbiology 40, 41-52.

A summary of experimental work undertaken in Northern Ireland confirming the ability of infected cattle to excrete *M. bovis*.

Olea-Popelka, F., Butler, D., Lavin, D., McGrath, G., O'Keefe, J., Kelton, D., Berke, O., More, S., Martin, W. 2006. A case study of bovine tuberculosis in an area of County Donegal, Ireland. Irish Veterinary Journal 59(12), 683-690.

A descriptive epidemiological analysis of risk factors contributing to the development of a cluster of 32 TB breakdowns in the reference area of Co. Donegal during the fifth year of the Four Area Project. The most likely reasons for this outbreak was residual (and recrudescence of) infection, cattle-to-cattle transmission between herds and, to a lesser extent, purchase of infected cattle. The authors called for a review of the Irish TB testing scheme whereby cattle can be freely sold, without further testing, for 365 days after a herd passes its annual screening test.

Phillips, C.J.C., Foster, C.R.W., Morris, P.A., Teverson, R. 2003. The transmission of *Mycobacterium bovis* infection to cattle. Research in Veterinary Science

74, 1-15. This article presents the findings of the Independent Panel on TB and Cattle Husbandry, which reported to MAFF in May 2000. In this review of the mechanisms of transmission of *M. bovis* between cattle and from wildlife to cattle, the authors concluded that there was evidence suggesting that badgers are the greatest contributors to infection in cattle in the British Isles. Nevertheless, they also estimated that the [translocation of cattle and onward] transmission of the disease between cattle following movements could account for 10-15% of TB breakdowns in the British Isles. They recommended that farmers bringing cattle into a herd should consider pre- or post-purchase tuberculin testing and quarantine.

Roberts, A.R. 2004. The influence of selected herd factors with the occurrence of bovine tuberculosis in a region of Northern Ireland. MSc dissertation, University of London. The author undertook an observational study of TB in a high incidence area of Northern Ireland and concluded that the number of cattle purchased was a significant risk factor for TB breakdowns, although less so than the presence of TB in neighbouring herds.

Schoenbaum, M.A., Espe, B.H., Behring, B. 1992. Epidemic of bovine tuberculosis cases originating from an infected beef herd in Oklahoma, USA. Preventive Veterinary Medicine 13, 112-120. A case report describing how the dispersion of cattle following a sale from a chronically infected beef herd resulted in infection being disclosed in other 13 herds receiving cattle from the index case. These herds were also depopulated and the prevalence of infection among the in-contact animals was found to be 0.3% following tuberculin testing and post-mortem examination.

Wilesmith, J.W. 1983. Epidemiological features of bovine tuberculosis in cattle herds in Great Britain. Journal of Hygiene 90, 159-176. The author observed that, in 654 of 1099 infected herds in GB during the period 1972-1978 in which the source of infection could be identified, 42% involved purchased cattle (mostly imported from Ireland). When these were broken down by region, the fraction of breakdowns attributed to purchased infection was 8% in the SW of England against 64% in the rest of the country.

Wilesmith, J.W. and Williams, D.R. 1986. Tuberculosis lesions in reactor cows. Veterinary Record 119, 51. In this communication the authors indicated that, while the majority of herd breakdowns in SW England were attributed to infection from badgers, 10% were due to purchase of cattle.

Woolhouse, M.E.J. 2005. Dangers of moving cows. Nature 435, 431-432. An editorial on the article by Gilbert et al. (2005) cited above, highlighting the risks associated with the extensive movement of cattle between holdings. The author called for the Government to consider the introduction of "more effective TB control measures", including badger culling, statutory pre- and post-movement testing and possibly greater restrictions on cattle movements.