Hunger is one of the most important factors contributing to the deaths of 5000 people from TB every day worldwide.

‘We are at a party which does not love us.’

*Below Zero*
Tomas Tranströmer

*Eyes that Don’t Want to See and Ears that Don’t Want to Hear*
Lidzie Alvisa
Photography, Acrylic black box and pins; 23.5 × 24 cm each
INTRODUCTION

Bovine TB is a chronic disease of animals caused primarily by *Mycobacterium bovis* (*M. bovis*), a member of the *Mycobacterium TB* Complex. The disease is characterised by progressive development of specific granulomatous lesions or tubercles in the lung tissue, lymph nodes or other organs. The incubation period ranges from months to years but, acute stages of the disease can develop during the course of infection, when lesions progress rapidly.

*M. bovis* is of significant importance in livestock and in a wide range of wild animal species worldwide. Bovine species, including bison and buffaloes, are particularly susceptible to the disease, but nearly all warm-blooded animals can be affected (1, 2). *M. bovis* is also known to affect humans, causing a serious public health problem where the disease is endemic (1).

Like the human form of TB, bovine TB commands growing attention from the international community because of the serious increase in the number of infected herds and the subsequent effect on animal production, combined with the significant impact of *M. bovis* infection on public health and the permanent threat of infection from animal reservoirs. Despite the long history of disease recognition, the epidemiology of *M. bovis* is not well understood, especially in wildlife. In some developed countries, the disease has been eliminated from the livestock population, but in other countries wildlife reservoirs have been identified as reservoir hosts, posing a continuous threat and source of infection of cattle and making complete eradication difficult. In less developed countries, the disease continues to cause significant losses in the cattle farming sector with serious implications on public health, especially where surveillance and control programmes are weak or non-existant. In response to the global importance of bovine TB both for animal health and public health, the Food and Agriculture Organization of the United Nations (FAO) has recognised it as a serious infectious disease that should be controlled at national and regional levels in the interest of the livestock industry and of public health and human livelihoods.
This chapter does not aim to provide a comprehensive description of bovine TB which can be found already well-documented elsewhere (3–6), but rather to outline the main features of bovine TB in cattle and wildlife, the impact of bovine TB on public health and perspectives on its control, with particular reference to the situation in developing countries.

GLOBAL DISTRIBUTION AND SOCIOECONOMIC IMPACT

The geographical distribution of bovine TB has changed drastically over the past decades. Prior to the introduction of control measures and milk pasteurization in developed countries, TB has been widely distributed throughout the world. Eradication programmes based on test-and-slaughter policies to clear herds of infected animals virtually eliminated TB from livestock in many developed countries. Today, many countries in Europe and North America, and Australia are free of the disease or close to complete eradication in livestock. However, the maintenance of *M. bovis* infection by wildlife species has compromised eradication efforts in countries such as in the United Kingdom, Ireland, New Zealand and parts of the United States of America (4).

In developing countries, data on the prevalence of bovine TB are minimal, and the information available may not represent the true epidemiological status of the disease. Although bovine TB is notifiable in many countries, it is often under-reported, particularly in countries that lack effective disease surveillance and reporting systems. The insidious nature of the disease, which does not cause fulminating outbreaks with high mortality, is likely to decrease reporting of the disease, leading to a lack of measures for its control (7).

Despite disease under-reporting in developing countries, there is, however, sufficient evidence to indicate that not only the prevalence of disease is higher in the developing nations but also that in the absence of any national control and eradication programmes, it is increasing worldwide particularly in Africa (8, 9), Asia and Latin America (4). According to the Worldwide Animal Health Information Database (WAHID) of the World Organization for Animal Health (OIE), 70 countries reported bovine TB cases in their cattle populations in 2010 and 49 in 2011 (Figures 1.5.1–1.5.4).
Figure 1.5.1 Geographical distribution of bovine TB for 2011 based on OIE’s six monthly reports

Figure 1.5.2 Geographical distribution of bovine TB for 2010 based on OIE’s six monthly reports
Figure 1.5.3 Number of bovine TB cases reported by country to OIE in 2010

Figure 1.5.4 Number of bovine TB cases reported by country to OIE in 2011
The economic impact of bovine TB on livestock production is extremely difficult to determine accurately. The disease reduces livestock productivity in general and may be economically devastating for the cattle industry, especially the dairy sector. Milk yields and draft power can be significantly reduced with direct effects on the livelihoods of poor livestock holders. Most important is the impact of the risk of infection to humans, particularly for women and children who appear to be more susceptible to the disease in countries with poor socio-economic conditions and weak veterinary and public health services. Although estimates of the costs associated with bovine TB and its control refer only to specific countries, all data suggest that worldwide economic losses due to the disease are significant. These losses include those related to animal production, markets and trade as well as the costs of implementing surveillance and control programmes (10). Losses to TB are also extremely important when endangered wildlife species are involved.

**IMPACT OF M. BOVIS INFECTION ON HUMAN HEALTH**

Bovine TB is a zoonotic disease that can have serious consequences for public health. The transmission of *M. bovis* from cattle to humans was once common in industrialized countries, but human infections were virtually eliminated in countries with effective programmes for eradicating the disease in cattle and high standards of food safety, particularly the pasteurization of milk. The incidence of human TB due to *M. bovis* varies considerably among countries depending on the prevalence of the disease in cattle, socio-economic conditions, consumer habits, and practiced food hygiene (11). In developed countries, *M. bovis* generally accounts for an insignificant share of total TB cases in humans. It, causes less than 2 percent of all TB cases in the United States of America (12) affecting primarily immigrant populations from Mexico, and has been estimated to cause less than 1.5 percent of confirmed human cases in the United Kingdom (13). In the Netherlands, *M. bovis* infection represented about 1.4 percent of all TB cases during the period of 1993 to 2007 (14).

In developing countries, the occurrence of human TB due to *M. bovis* is difficult to determine accurately and probably remains under-reported, owing to the diagnostic limitations of many laboratories in isolating the microorganism and distinguishing
M. bovis from MTB (6). Prevalence of the disease is likely to be higher in countries where M. bovis infection is endemic in cattle and milk is not pasteurized. Some reports have speculated that M. bovis accounts for 10 to 15 percent of human TB cases (15), while other estimates range from 0.4 to 8 percent, demonstrating that M. bovis is an important factor in human TB (16). The consumption of untreated dairy products from infected cows is the usual mode of transmission of TB from animals to people. This mode is particularly dangerous for children who appear to be the most susceptible to the disease in rural areas. The infection can also occur through airborne transmission, especially where humans work in the immediate vicinity of infected cattle or carcasses and/or share the same premises with infected animals. People suffering from M. bovis TB can re-transmit the infection to cattle, but this is not common. Mounting evidence supports the likelihood of human-to-human, airborne transmission of M. bovis from patients with pulmonary disease, but the relative contribution of this mode to new infections in humans is unknown (17).

As is also true of human TB, the risk of M. bovis infection in humans is likely to increase where the prevalence of HIV/AIDS is high due to the susceptibility of immunosuppressed AIDS patients to TB. Cases of HIV-related human TB due to M. bovis have been reported in many developed countries (18). The potential impact of AIDS/HIV infections in humans on the transmission of M. bovis to and among humans, is of great concern and requires careful consideration, wherever bovine TB is still a major problem (16, 18).

**TB IN WILDLIFE**

Bovine TB has emerged as an increasingly important disease of both captive and free-ranging wildlife populations (19, 20). TB in wildlife increases public health concerns and interferes with TB eradication programmes in cattle (21). M bovis can infect a wide range of wild animals, which can act as either reservoir hosts, capable of maintaining and spreading the infection by intraspecies transmission, or spillover hosts, when infection is not maintained in the wildlife population (5, 21). The range of wild host and reservoirs of infection varies among regions. The African buffalo (Syncerus caffer) is considered to be a maintenance host for M. bovis in South Africa’s Kruger national park (3) with infection spilling over to other
wildlife species in the park (22). Wapiti (*Cervus elaphus*) and bison (*Bison bison*) are considered wildlife reservoirs of *M. bovis* infection in Canada (23); the white-tailed deer population is the first acknowledged wildlife reservoir of bovine TB in the United States of America (24); European badger (*Meles meles*) populations are reservoir hosts in the United Kingdom and Ireland (21, 25, 26); and brushtail possums (*Trichosurus vulpecula*) are the primary wild maintenance hosts of bovine TB in New Zealand. TB in captive deer or wild cervids has been observed in many countries in Europe and North America. There is increasing evidence that wild boars (*Sus scrofa*), long thought to be the spill-over hosts are maintenance hosts of *M. bovis* for other wildlife and domestic animals in Europe (29-31). Wildlife may contaminate cattle through either direct or indirect contact and many questions remain regarding wildlife and *M. bovis* transmission at the livestock interface. Although direct transmission is probably rare it, may be possible when infected animals are at late stage of the disease. Indirect transmission is more frequent through the contamination of the environment, water and through the feeding by excretions of wildlife (5).

**OPTIONS FOR CONTROL AND ERADICATION OF BOVINE TB**

Control and eradication of bovine TB is a desirable objective both from an animal health perspective and also because of the zoonotic implications of *M. bovis*. Control and eradication have been achieved in many countries through test and slaughter policy and surveillance at slaughterhouses.

**Surveillance of bovine TB and testing tools**

The Tuberculin Skin Test is the standard tool for detecting TB in live animals and is the primary cattle screening tool available currently. It is referred to as single intradermal test, when bovine tuberculin is used alone and as intradermal comparative test when both bovine and avian tuberculins are used (32). The latter can distinguish between infections with *M. bovis* and sensitization to other Mycobacteria species. The Tuberculin Skin Test has been widely applied for screening purposes in eradication campaigns, with successful results in many countries (33).
Nevertheless, the test has limitations including difficulties in interpreting the results and imperfect test accuracy (13). This lack of performance, can impede progress in a herd sanitation programme using test and slaughter (34). Unnecessary elimination of false positive reactors may also have serious implications on cattle management (5). Additional limitations are related to the time, and the need to handle animals twice for the administration of the tuberculin and 72 hours later for reading of the reaction.

Several other tests have been developed to improve the diagnosis and screening of bovine TB (35). Among these is the Interferon Gamma Assay which detects the production of gamma-interferon by the T-lymphocytes in the blood (36). Studies on the specificity of this test have contributed to significant improvement in the detection of *M. bovis* in cattle and wildlife populations. However, the Interferon Gamma Assay is not used routinely for the diagnosis of bovine TB and it appears to be impractical for use in developing countries as it requires delivery of the samples to the laboratory within 24 hours for processing using relatively sophisticated and expensive techniques (3, 13).

Studies have compared the sensitivity and the specificity of the Tuberculin Skin Test and the Interferon Gamma Assay (36, 37). These studies showed that for both tests results may differ depending on the conditions in which the test is performed, the used reagents, the chosen cut-off point, the stage of development of the infection and the immune status of the animal. (11).

The identification of bovine TB through meat inspection at slaughterhouses is another important surveillance instrument, although its sensitivity is rather low. Abattoir surveillance can be used as a cost-efficient method alone or combined with routine cattle testing, depending on the prevalence of the disease in the country. However, this assumes reliable meat inspections practices to be supported by an efficient animal identification system and adequate record keeping at both the farmer and the slaughterhouse levels.
Test and slaughter

Effective implementation of the test and slaughter policy has been the way by which most countries have achieved eradication or markedly reduced the prevalence of bovine TB in cattle. Herds are tested using the Tuberculin Skin Test and reactors are immediately removed for slaughter. The herds are then re-tested after prescribed periods until no further reactors are detected, and there is no evidence of tubercules in reactors at slaughter (13). The success of control programmes based on the test and slaughter strategy depends on institutional and technical requirements including:

- an efficient cattle identification system that allows effective tracing back to the herds of origin of tuberculous animals detected through slaughterhouse surveillance;
- a high standard of meat inspection practices enabling effective surveillance for tuberculous lesions in animals passing through slaughterhouses;
- an animal health information system for recording relevant information including epidemiological investigations, and data analysis to monitor progress and guide decision making;
- a legal framework for enforcing control measures and compensating farmers for the slaughter of tuberculin positive reactors;
- full control of movements of cattle including cross-border transhumance;
- political support with cooperation of stakeholder groups involved and public awareness to ensure the success of the bovine TB control and eradication programme;
- public awareness campaigns and sensitization of farmers and the general public on bovine TB hazards and hygiene practices, and awareness of the objective, benefits, challenges and other implications of surveillance and control;
- incentives for farmers to adhere to the eradication programme, such as guaranteed milk prices and setting subsidies for disease free herds;
- laboratory diagnostic capability for TB diagnosis based on the isolation and species identification of the bacterium from tuberculous lesions on organs, and
- financial resources, for adequate and speedy compensation of farmers for losses due to the removal of infected animals.
Treatment and vaccination

The treatment of TB in livestock with drugs has had limited success and is forbidden in most countries, particularly because of the potentially increasing the drug resistance of mycobacterium. In a few occasions, captive exotic animals have been treated with medications (4), but this was not considered viable for herds of free-ranging animals (3). At present, control or eradication of TB by means of treatment using antibiotics is neither feasible nor recommended.

Currently, the only vaccine used against *M. bovis* infection is the human vaccine Bacille-Calmette-Guerin (BCG), which is a live attenuated strain of *M. bovis*. Apart from the limited efficacy of BCG vaccine in cattle, it could also compromise the tuberculin skin testing of animals (38, 39). Despite the promising results from recent studies in cattle and wildlife, so far, no practical or effective vaccination approaches have been developed for any animal species. With advanced research on the genome sequences of *M. bovis* and the BCG vaccine, and the development of other types of vaccines such as subunit vaccines in the form of deoxyribonucleic acid (DNA) vaccines or adjuvated protein subunit vaccines, it may become feasible to design and develop effective mycobacterial vaccines and vaccination strategies, for preventing or controlling bovine TB in cattle or wildlife (39).

Limitations to bovine TB surveillance and control in developing countries

In developing countries, bovine TB is still common, especially in the dairy sector. The upsurge in peri-urban dairy production, unregulated animal movement, lack of animal identification, lack of surveillance at slaughterhouses, and weak veterinary services all contribute significantly to the poor control of animal TB in these countries (5).

Although regular tuberculin skin testing and the elimination of infected animals have been successful in eliminating, or significantly reducing bovine TB from cattle herds in many developed countries, these control measures are not affordable and may not be practical in many parts of the world. In some cases the policy of test and slaughter is in place but it is not always vigorously pursued, and positive reactor animals may not be effectively quarantined or culled. This is largely because...
of legal and economic constraints such as the high cost of sustainable testing and slaughter of infected animals and the subsequent compensation to farmers (40). Results may therefore be the opposite of those intended with the policy, contributing to the spread of disease through the sale of reactors. It is likely that some countries make a point to adopt feasible strategies for progressive control of animal TB by introducing interim measures such as segregation and phased slaughter of reactors, while improving biosecurity on farms. Although this approach may reduce the economic loss for the farmer, its usefulness may be limited by the difficulty of managing the segregation of reactors.

Limited laboratory diagnostic capacity is one of the major constraints to bovine TB control programmes in many developing countries. The diagnosis of TB is usually limited to the microscopic observation of the micro-organism on smears, making it difficult to investigate infected cases and identify the strains of *Mycobacterium* involved (40).

Post-mortem inspection at slaughterhouses is a cost-efficient method for passive surveillance of bovine tuberculosis. However, the quality of detection of tuberculous lesions in slaughterhouses can vary within the same country (41) with implications for the effectiveness of surveillance. In addition, routine post-mortem surveillance may not be possible if slaughtering facilities are limited. For instance, in many African countries there are few abattoirs and more than 50 percent of slaughters take place informally with no meat inspection performed (42). When abattoir surveillance data do exist, they are not always integrated into the national official notification system and so are not used effectively.

Insufficient collaboration at regional level, lack of quarantine and border security as well as illegal movements across borders between neighboring countries have also been identified as factors contributing to the persistence of bovine TB and undermining control efforts in several developing countries.

Rural communities in many developing countries are not aware of the risk factors associated with the transmission of bovine tuberculosis, and their living conditions often promote the spread of *M. bovis* infection in humans. In these situations, the risk of zoonotic transmission should be addressed through education and prevention programmes to inform cattle owners about the risks of bovine TB and the necessity for pasteurizing milk and inspecting carcasses after slaughter.
CONCLUSION

Bovine TB remains of great concern worldwide. In developed countries, significant progress has been made in controlling and eradicating the disease in cattle primarily via test and slaughter strategies and in humans via improved hygiene practices and pasteurization of milk. However, eradication programmes in some countries are constrained by the presence of endemic infection in wildlife reservoir hosts. The maintenance of ongoing multi-sectoral research efforts is necessary to improve the understanding of the role of wildlife host reservoirs in the dynamics of *M. bovis* infection in cattle and also to develop sustainable control strategies using a variety of tools and measures targeting both cattle and wildlife. Many authors support the introduction of control options that include the development of appropriate vaccines and their deployment in vaccination of wildlife where test and slaughter programmes have failed. Improved testing tools and additional research on *M. bovis* are also needed.

In developing countries, the disease continues to cause significant losses in the cattle industry, with implications for food security and trade. In the absence of effective surveillance and control strategies, bovine TB continues to be a major public health problem, especially in countries where the prevalence of infection in cattle is high, consumption of raw milk products is common, and malnutrition and other immunodepressive conditions exacerbate the danger of the infection. The impact of bovine TB on public health is likely to worsen given the potential increase in drug resistance of *M. bovis* in situations where human infections are not effectively treated. There are still critical gaps in the understanding of disease patterns, the real extent of the disease in cattle and other animals and the strains involved. Better surveillance of bovine TB is required in many countries, through improved post-mortem inspection, efficient tracing of infected animals to their herds of origin, regular tuberculin skin testing and effective laboratory diagnostic support. There is also need for qualified veterinary staff at the slaughterhouses to ensure adequate meat inspection practices and standards. Effective implementation of these activities would allow countries to generate quality data and acquire sufficient knowledge of the epidemiology of the disease, for developing strategic, cost-efficient and effective control programmes. From successful experience in many developed countries, it can be concluded that bovine TB can be controlled only when there is a strong political and producer support, an appropriate legal framework to enforce control measures, and active participation of all concerned in finding practical and affordable control options that are suitable for each country and each epidemiological context. Eradication is a more difficult target and requires many factors to be in place, including the necessary financial resources.
TB due to *M. bovis* has a complex epidemiological pattern which includes the transmission of infection within, and among humans, domestic animals, and wildlife. Control and eradication of bovine TB provides an ideal platform for the One Health approach, which can be operationalized through adapted approaches for improving surveillance and meat inspection, enhancing community awareness, promoting milk pasteurization at the community level, and strengthening inter-sectoral collaboration. The FAO is working in this direction by developing and implementing a One Health approach for comprehensive and integrated control of animal diseases that have impacts on public health, food security and human livelihoods.

**REFERENCES**


