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Bovine tuberculosis at the human–livestock–wildlife interface and its control through one health approach in the Ethiopian Somali Pastoralists: A review

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ABSTRACT

Pastoralism is a way of life in which food supply is produced from animals by using a variety of herding practices based on constant or partial herd mobility in the low land areas of Ethiopia. It covers 12% of the total livestock population and 61% of the total area of land in the country. As a result of their mobile lifestyle, pastoralists are almost completely excluded from the available health services. This review article focuses on bovine tuberculosis in the Ethiopian Somali Pastoralist. It describes *Mycobacterium bovis* in humans, livestock, and wildlife, and how the disease can be controlled by using One Health approach. Bovine tuberculosis is a chronic bacterial disease caused by *Mycobacterium bovis*. A study done from 2006 to 2008 on the prevalence of BTB in Ethiopian wildlife showed that sera from 20 of 87 animals (23%) were positive for BTB. In Ethiopia there is no comprehensive report about the status of *M. bovis* in wildlife populations that often share habitat with livestock**.** A study done on bovine tuberculosis in Somali pastoral livestock showed low prevalence of the disease. An individual animal prevalence of 2.0%, 0.4%, and 0.2% was reported in cattle, camels, and goats, respectively. In a simultaneous human and cattle study in a pastoralist areas of south-eastern Ethiopia, out of 163 human *Mycobacterium tuberculosis* complex isolates three were *M. bovis*. Due to the moderate resistance of the etiological agent to the environmental conditions in one hand and the capacity of its survival in acid milk for not less than 15 days on the other and the habitual consumption of unpasteurized milk by humans make this disease a vital zoonosis in Somali pastoralists in Ethiopia. *M. bovis* is a pathogen at the human-livestock-wildlife interface. Diseases transmitted between humans, livestock, and wildlife are increasingly challenging public and veterinary health systems. Therefore, studies concerning the burden of the diseases in wildlife, livestock and human beings in Somali Pastoralists should be undertaken. A One Health approach that takes the wellbeing of the pastoralists, the health of their livestock and environment into consideration is also necessary for the control of BTB.

1. Introduction

Zoonotic diseases are responsible for most (60.3%) emergent diseases of humans. Moreover, the preponderance (71%) of emerging pathogens is of wildlife origin or has an epidemiologically important wildlife host [29]. Wild animals are susceptible to infection by many of the same pathogens that afflict domestic animals, and transmission between domestic animals and wildlife can occur in both directions. Nevertheless, the original event was often the transmission of a domestic animal disease to wildlife [17].

Diseases transmitted between humans, wildlife, and domestic animals are increasingly challenging public and veterinary health systems [39]. In North America, it is estimated that at least 79% of reportable domestic animal diseases have a putative wildlife component associated with the transmission, maintenance, or life cycle of the pathogen and at least 40% are zoonotic [28]. Similarly three-fourths of all emerging infectious diseases (EIDs) of humans are zoonotic with most originating from wildlife reservoirs (Talor et al [40]). Therefore, diseases that arise from the livestock–wildlife interface are of paramount importance and must be an area of focus for public and veterinary health systems. Despite this importance cross-species transmission is one of the least studied aspects of disease ecology [29]. One such pathogen is *Mycobacterium bovis*, the causative agent of tuberculosis in cattle and most other mammals, wild or domestic. Importantly, its remarkably broad host range includes humans [22].

Bovine tuberculosis (bTB) is a chronic granulomatous disease of cattle. The disease is transmitted between animals primarily by inhalation although transmission through ingestion is also common in cattle grazing on pasture contaminated with *M. bovis*. The disease causes significant animal health-induced economic loss, and its impacts include reduction in productivity, movement restrictions, screening costs, culling of affected animals, and trade restrictions [49].

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Pastoral communities in the Ethiopian Somali Region move from place to place in search of feed and water for their animals. Mobile pastoralists in Africa including the Somali pastoralists cope with drought and difficult weather conditions through transhumance, taking their animals to the rangelands with the highest quality and quantity of forage. This opportunistic grazing strategy closely tracks resources, which is a highly appropriate and effective way to deal with the variable, unpredictable, and heterogeneous environments of Africa's dry lands [41]. As a result of their mobile lifestyle, pastoralists are almost completely excluded from currently available health services [63].

Whereas earlier ethnoveterinary research on pastoral systems focused primarily on animal health [35], there has been an increasing interest in research projects that examine animal and human health as an integrated system [65]. These integrative projects are informed by the concepts of One Medicine and One Health [30] An integrative approach to human-animal health is particularly relevant in pastoral systems in which keeping livestock is not only a way to make a living but also a way of life [64]. Therefore, this review article focuses on bovine tuberculosis (BTB) in the Ethiopian Somali Pastoralist, which is an example of a pathogen shared at the human–livestock–wildlife interface. It will describe *M. bovis* in humans, domestic animals, and wild animals, and how the disease can be controlled by using an integrated health (One Health) approach.

2. Bovine tuberculosis

Bovine tuberculosis (BTB) is a chronic bacterial disease caused by *Mycobacterium bovis*, a Gram positive, acid-fast bacterium. This pathogen belongs to the *Mycobacterium tuberculosis* complex, a group of genetically closely related mycobacteria. *Mycobacterium tuberculosis*, *Mycobacterium bovis*, *Mycobacterium bovis BCG, Mycobacterium canettii*, *Mycobacterium africanum, Mycobacterium pinnipedii, Mycobacterium microti, Mycobacterium caprae*, the *dassie* and the *oryx bacillus*, and the recently discovered *Mycobacterium mungi* are closely related species that form the M. tuberculosis complex (MTBC). *Mycobacterium tuberculosis* and *M. bovis* are the most important species in the complex which commonly cause human and animal tuberculosis (TB), with concomitant negative consequences for human and animal health and economic costs [31]. Although cattle are considered to be the main host*, M. bovis* also affects many other livestock and wildlife species. The disease is a significant zoonosis that can spread to humans, typically by the inhalation of aerosols or the ingestion of unpasteurized milk. In developed countries, eradication programs have reduced or eliminated tuberculosis in cattle, and human disease is now rare; however, reservoirs in wildlife can make complete eradication difficult [48]. Because of their close proximity to livestock, pastoralists face high risk of exposure to zoonotic diseases such bovine tuberculosis, many of which are endemic in much of sub-Saharan Africa [67]. On top of its economic impacts, bTB is transmitted to humans, and prior to mandatory pasteurization about one-fourth of TB cases in children was caused by *M. bovis* in developed countries while 15% of human TB up until the end of 1990's was believed to be caused by *M. bovis* in developing countries [68]. A more recent study however, reported a much lower figure of 2.8% of human TB to be attributed to *M. bovis* in Africa Muller et al. [43].

3. BTB in the Ethiopian wildlife

In countries with suspected or confirmed wildlife reservoirs of *M. bovis*, multiple species are epidemiologically linked and may include multiple reservoir hosts and multiple routes of transmission [8,46]. Recognized wildlife reservoir hosts of *M. bovis* include the brushtail possum (*Trichosurus vulpecula*) in New Zealand, European badger (*Meles meles*) in Great Britain and Ireland, African buffalo (*Syncerus caffer*) in South Africa, wild boar (*Sus scrofa*) in the Iberian Peninsula and white-tailed deer (*Odocoileus virginianus*) in Michigan, USA [50].

A study done from 2006 to 2008 on the prevalence of BTB in Ethiopian wildlife showed that sera from 20 of 87 animals (23%) were positive for BTB. None of the positive cultures in this particular study yielded mycobacteria from the *Mycobacterium tuberculosis* complex but many environmental mycobacteria were isolated. This shows a high prevalence of environmental mycobacteria in wildlife, the role of which is unknown [58]. However, the presence of the aforementioned animals in different wildlife reserves and even in free ranging forests may have an epidemiological role in the spread of the disease among other wild and domestic animal species [26]. The widely distributed Rock hyrax (*Procavia capensis*) might also be a possible reservoir of BTB in Ethiopia [1]. In Ethiopia there is no comprehensive report about the status of *M. bovis* in wildlife populations that often share habitat with livestock.

4. BTB in the Ethiopian Somali Region livestock

Pastoralism is a way of life in which food supply is produced from animals by using a variety of herding practices based on constant or partial herd mobility in the low land areas of Ethiopia. It covers 12% of the total livestock population and 61% of the total area of land in the country [40].

Bovine tuberculosis has been shown to be present in most countries in Africa, but the true extent of the disease has not been evaluated and genotype surveys are often limited in scope [3]. Cattle are considered to be the main host for *M. bovis* and the disease has considerable economic impact on the agricultural and trade sector [62].

In Ethiopia most of the BTB studies in livestock are conducted in and around urban areas in the central highlands and there are few studies concerning remote areas like Somali Region pastoral communities [6]. A study done on bovine tuberculosis in Somali pastoral livestock showed low prevalence of the disease. An individual animal prevalence of 2.0%, 0.4%, and 0.2% was reported in cattle, camels, and goats, respectively [5]. BTB in camels of eastern Ethiopia was studied for the first time in 2009 in order to describe its prevalence and to isolate *M. bovis* from infected camels as the causative organism [19]. Despite continuous close contact, and sharing of pastures with potentially infected cattle, the prevalence based on single intradermal cervical comparative tuberculin (SICCT) test in small ruminants is very low [57].

5. BTB in the Ethiopian Somali Pastoralists

In Sub- Saharan Africa, nearly 2 million tuberculosis cases in humans occur each year; yet it is unknown what role BTB plays in the rising epidemic of tuberculosis fostered by HIV/AIDS [62]. Bovine Tuberculosis cases reported in humans are few despite the disease being endemic in livestock, the often close relationship between people and livestock in rural Africa, and the lack of milk pasteurization and meat inspection [10]. A meta-analysis by Müller et al. [43] showed that a median 2.8% of all TB cases in humans were attributable to *M. bovis* in Africa, with significant country variations. In countries where BTB in cattle is still highly prevalent, pasteurization is not widely practiced and/or milk hygiene is insufficient, it is usually estimated that about 10% to 15% of human tuberculosis is caused by BTB [51].

According to a study conducted in pastoral communities in the northern part of Tanzania, the risk factors for bovine tuberculosis in man are found to be similar in most pastoral settings. BTB in the human population mainly takes place through drinking raw milk and occur in the extra-pulmonary form in the cervical lymphadenitis form in particular [36].

Kidane et al. [32] indicated that *M. bovis* was found to be a cause for tuberculous lymphadenitis in 17.1% of 29 human tuberculosis cases in Ethiopia. In a simultaneous human and cattle study in a pastoralist area of south-eastern Ethiopia, out of 163 human *Mycobacterium tuberculosis* complex isolates three were *M. bovis.* One of them had the same spacer spoligotype as strains isolated from cattle in the same study area [24].

Due to the fact that the moderate resistance of the etiological agent to the environment in one hand and the capacity of its survival in acid milk for not less than 15 days on the other and the habitual consumption of unpasteurized milk by humans make this important disease a vital zoonosis in Somali pastoralists in Ethiopia [14].

All reported human BTB cases are of livestock origin and to date there are no published reports of direct BTB transmission from wildlife to humans in Africa. However, it is most likely that human cases are under-reported due to the lack of data gathered on human disease burden, the lack of diagnostic facilities and poor disease knowledge, particularly from the wildlife side [15].

6. BTB at the human–livestock–wildlife interface

Diseases transmitted between humans, domestic animals, and wildlife are increasingly challenging public and veterinary health systems [38]. In North America, it is estimated that at least 79% of reportable domestic animal diseases have a putative wildlife component associated with the transmission, maintenance, or life cycle of the pathogen and at least 40% are zoonotic [39]. Similarly three-fourths of all emerging infectious diseases (EIDs) of humans are zoonotic with most originating from wildlife reservoirs [56]. Therefore, diseases that arise from the livestock–wildlife interface are of paramount importance and must be an area of focus for public and veterinary health systems [55]. Despite this importance cross-species transmission is one of the least studied aspects of disease ecology [34].

Human–livestock–wildlife interface is not a standard concept but rather one that varies tremendously across Sub-Saharan African pastoralists depending on human, livestock and wildlife densities and their movements (e.g. migration, transhumance), wildlife species, environmental factors and anthropogenic land-use change [63].

Mycobacterium bovis is an example of a pathogen shared at the human–livestock–wildlife interface [4]. The list of wildlife species around the world from which *M. bovis* has been isolated is long and reports in the literature of new susceptible species have increased in recent years. Some wildlife species have long been known to be maintenance hosts (i.e., wildlife species that can maintain the disease in the absence of infected cattle). Classic examples of maintenance hosts include the brushtail possum (*Trichosurus vulpecula*) in New Zealand [12], the white-tailed deer (*Odocoileus virginianus*) in the USA [47], the Eurasian badger (*Meles meles*) in the UK and Ireland [23], the African buffalo (*Syncerus caffer*) in South Africa [16], and more recently described, the wild boar (*Sus scrofa*) in Spain [44] and wood bison (*Bison bison*) in Canada [45]. These maintenance hosts are a source of infection for livestock and can also be described as a source for BTB in humans that have close contact with infected animals, such as hunters and game farmers [60].

Rainfall and water shortages are the main drivers and constraining factors for the distribution and abundance of wildlife species and thus for contact opportunity between species. Interaction between different wildlife species around natural and artificial water sources have been described [18]; but how wildlife and livestock interact is poorly known. Zvidzai et al. [66] studied livestock–wildlife at water points located within Gonarezhou National Park (Zimbabwe), at the park boundaries and in the agricultural area. The authors concluded that BTB transmission was unlikely to be caused by direct contact at the interface around water sources. However, intermediate species such as impala, kudu and warthog (*Phacochoerus africanus*), which are less affected by livestock presence [52], could play a role as disease 'vector' by having close physical contact with BTB buffalo reactors, that stay within the park, and with livestock in the agricultural land outside the park.

Common use of pasture land is another potential risk for BTB transmission between wildlife and livestock. Mainly wildlife grazer species (as opposed to browser species) are likely to compete with cattle. There seems to be a species-specific tolerance level for cattle presence [61]. Many grazer species favour grazing in old pastoral places where grass cover is rich due to the cattle manure [53]. As *M. bovis* can be excreted in cattle manure and survive in the environment over days and months [27], it is worth remembering that disease transmission can still occur even with a temporally asymmetric interface (with no direct animal contact). Presence and abundance of wildlife species is also affected by the vegetation cover [42]. If the latter is altered naturally or anthropogenetically, wild animals will move elsewhere [25], likely shifting the existing dynamics of the interface.

Mycobacterium bovis has been designated a multi-host pathogen, for which open ecosystems provide almost unrestricted opportunities for pathogen exchange between domestic and wild animals [54]. Cattle have historically played a key role in the introduction of BTB into wildlife conservation areas in many countries. Once endemic, the possibility for spillback from wildlife to livestock and humans constitutes an animal and public health risk to communities neighboring infected wildlife reserves [21]. *Mycobacterium bovis* transmission at the wildlife–livestock-human interface is driven by contact with infected animals or through sharing water and grazing resources, following which the infection in livestock may pose a zoonotic risk to farmers and consumers of infected milk [37].

In rural areas of Ethiopian Somali Region, people drink raw milk and do have extremely close attachment with their animals and that intensifies the transmission of BTB from livestock to human beings. Detection of *M. bovis* from raw milk [33] confirms the existing problem and the potential risk of the infection in humans. Transmission of *M. bovis* at the livestock-wildlife or human-animal interface occurs essentially because of overlap in their territories. Generally the Human-Livestock–Wildlife Interface is poorly studied in Ethiopia and Somali Pastoralists in particular [7,15] (Fig. 1.

7. Control of BTB through one health approach

Control of bovine tuberculosis in pastoral communities, where livestock move from one place to another searching for grazing and watering points is not easy. This situation is exacerbated during drought, when nomadic tribes move and establish temporary settlements in areas where grazing land and water are available. According to Collins (2006), the success of a national BTB eradication programme, include a clear identification of the goals, of the policies that guide actions and of the sequences of actions that are required within the programme to accomplish these goals.

So far, BTB control in African wildlife has included culling, fencing, corridors kept free of animals, as well as a combination of these or a do-nothing strategy. All approaches have drawbacks, ranging from inefficiency to interference with wildlife migration leading to decreased wildlife population, and even mass mortality [9].

In most parts of Ethiopia, animals are kept near dwellings and maintained under very poor management and hygienic status, thus increasing the risk of acquiring infection for animals and humans. Creating awareness among the people to meet the standard hygienic requirement and to improve husbandry practices have been described to have a paramount importance in BTB control. In sub-Saharan Africa, BTB vaccination research in livestock [2] is ongoing but has shown various successes so far.

In general, human tuberculosis can be effectively controlled through BCG vaccination and employment of chemotherapy [59]. In Ethiopia, health education is practiced as one of the pivotal means to control TB through increasing awareness of the community about the disease. In pastoral areas where people have the habit of consuming raw milk and meat, public education about hygienic practices like milk pasteurization has been described to be very important [13].

One Health can be defined as any added value in terms of health of humans and animals, financial savings or environmental services achievable by the cooperation of human and veterinary medicine when compared to the two medicines working separately [63].

Although few examples of comprehensive One Health

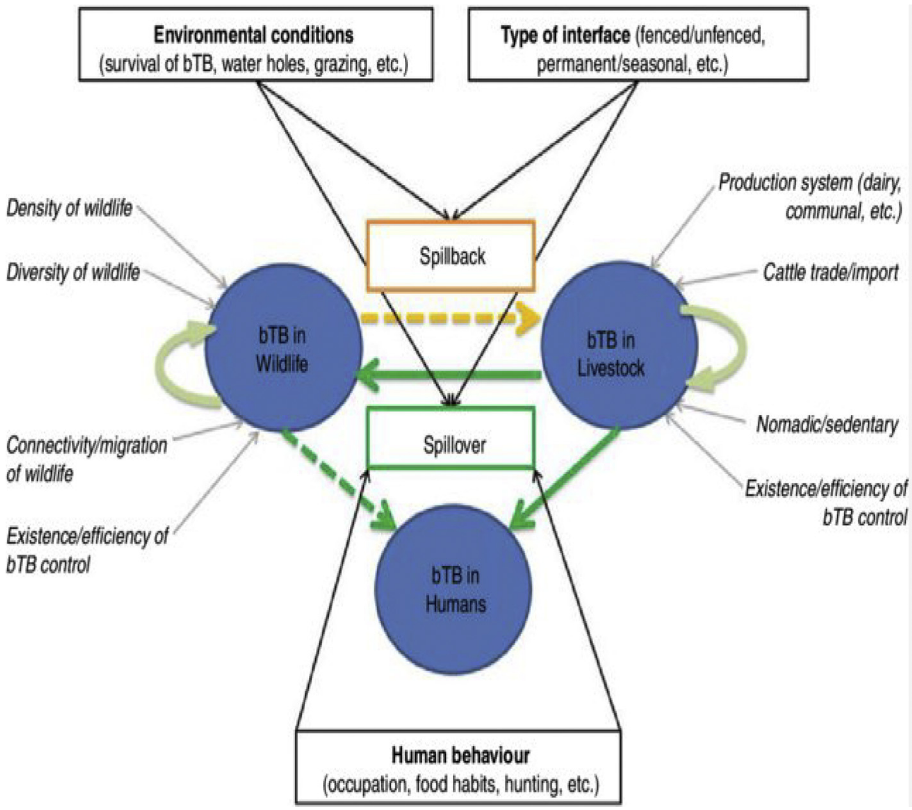

Fig. 1. Interspecific transmission of bovine tuberculosis (bTB) at wildlife–livestock–human interfaces in Africa. Bovine TB can be maintained in livestock (bTB in livestock) and in wildlife (bTB in wildlife), promoted by factors indicated in italics with a grey arrow (e.g. diversity of wildlife, production system). Risks of bTB spillover from livestock to wildlife or humans, and spillback from wildlife to livestock, are indicated in boxes with black arrows (e.g. environmental conditions, human behavior, etc.) .

implementation exist, they not only provide a useful framework for addressing the types of disease problem that involve complex interactions between people, animals and the environment, but also offer a way to develop and implement more effective, appropriate and acceptable strategies for disease control and prevention [11].

The need for multidisciplinary research to solve today's complex health and environmental challenges has never been greater. The One Health approach addresses questions at the intersections of human, animal, and environmental health by utilizing the expert knowledge of public health practitioners and clinicians, from multiple disciplines and at local, national, and global levels. While the need for multidisciplinary approach is not new, the concept of One Health has gained momentum as professionals from human medicine, public health, veterinary medicine, and environmental science increasingly focus on holistic, integrated approaches to complex questions that address human health in conjunction with animal and environmental health [20].

There is interdependence between people–livestock– wildlife and the environment that requires intersectoral collaboration in BTB control, so that it benefits livestock and wildlife-related economies, people's health and livelihoods, as well as biodiversity conservation. The BTB example shows the important added value of an implementation of intersectoral collaboration between public health, the agricultural and the wildlife sectors [69].

8. Conclusion and recommendations

The prevalence of BTB in Somali Region livestock is reported to be low. However, no studies concerning the burden of the disease in wildlife and human beings were undertaken and this indicates that BTB is not well studied in the Region especially in the Somali mobile pastoral communities. Human-livestock-wildlife interaction is dynamic. There are no sufficient studies clearly indicating the role of humans, livestock, wildlife and their environment with respect to the transmission dynamics of *Mycobacterium bovis* in the Ethiopian Somali pastoral areas. *Mycobacterium bovis* is an example of a pathogen shared at the human-livestock-wildlife interface. Therefore, studies concerning the burden of the diseases in wildlife, livestock and human beings should be undertaken. A One Health approach that takes the wellbeing of the pastoralists, the health of their livestock and environment into consideration is also necessary for the control of BTB.

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