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Options for the control of tsetse-transmitted livestock trypanosomosis. An epidemiological perspective

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ABSTRACT

Tsetse-transmitted livestock trypanosomosis affects livestock in large parts of sub-Saharan Africa. In southern Africa two epidemiological situations can be distinguished. The disease can have an endemic nature with high morbidity and low mortality in the livestock population. Endemic livestock trypanosomosis is found mainly in areas where cattle constitute the main host of tsetse and reservoirs of trypanosomes. Epidemic trypanosomosis, with high morbidity and high mortality is found in areas where wildlife persist as main reservoir and where livestock come into contact with tsetse flies transmitting trypanosomes from the sylvatic reservoir. Based on the differences in impact of the disease on livestock health in these two epidemiological settings, the appropriateness of the available trypanosomosis control tools differs. In trypanosomosis endemic areas, trypanocidal drug use could be the most suitable approach. Possible problems associated with the development of resistance in trypanosomes to the drugs need to be investigated further. In epidemic situations, vector control seems the most appropriate long-term solution.

1. Introduction

Tsetse-transmitted livestock and human trypanosomosis are important parasitic diseases affecting livestock and people in extensive parts of sub-Saharan Africa. Because of the important direct and indirect effects on livestock and agricultural production and its burden on human health many efforts have gone into the development of tools to control the disease. Although there is a continent-wide initiative to eradicate tsetse from the African continent, it will take considerable time before this is achieved (PATTEC, 2005). In the meantime, solutions for the problems that can be sustained on a small scale need to be found. Question remains, what can realistically be done and what is really required?

The formulation of strategies for the control of diseases, in general, and tsetse-transmitted trypanosomosis, in particular, is a dynamic process in which priority areas for sustainable tsetse and/or trypanosomosis control have to be identified, ranked and adjusted over time by asking questions including why, how, where, when and by whom trypanosomosis should be controlled. To address these questions properly a multidisciplinary approach has to be adopted by carefully screening potential control options based on a range of criteria including socio-economic, institutional, technical and environmental ones. Such a multidisciplinary approach has been adopted in countries of southern Africa (Van den Bossche and Doran, 2002). The outcome of the planning process indicated that generalisations about the direct and indirect impacts of bovine trypanosomosis and the sustainability and transferability of the different control techniques should be avoided. System specific information is required to ensure that the impact of the disease at the farm level is properly understood. In this respect, meaningful strategies for control

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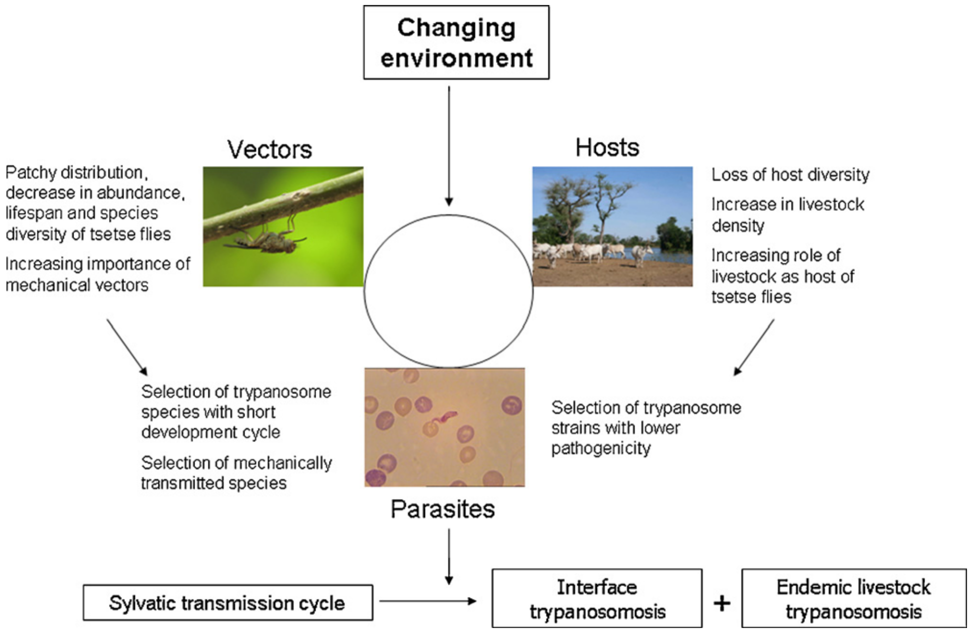

Fig. 1. The effect of climate change on the vector/host/parasite relationship in tsetse-transmitted trypanosomosis and its repercussions for the epidemiology of the disease.
Reprinted from Van den Bossche et al. (2010).

could be devised by relating disease impact and epidemiological data to each other.

Field studies conducted in southern Africa and supported by laboratory-based investigations have recently shed more light on this relationship between disease impact and epidemiology (Van den Bossche et al., 2010). This article considers the control of livestock trypanosomosis in southern Africa from an epidemiological perspective taking account of these spatial and temporal variability and its repercussions for the impact of the disease on livestock.

2. Anthropogenic changes and the epidemiology of livestock trypanosomosis

The African continent is experiencing considerable environmental changes as a result of an unprecedented demographic growth. The increasing human pressure and the demand for arable land is a major drive of land-use change resulting in deforestation, erosion and loss of biodiversity and suitable habitats for tsetse flies (*Glossina* spp.) (Van den Bossche et al., 2010). Like many other arthropods, tsetse flies rely for their survival on habitats with suitable conditions. The destruction and fragmentation of habitats has had important repercussions for the density and distribution of tsetse flies. In some instances, the drastic changes have resulted in the disappearance of certain species (Courtin et al., 2009). In many cases, however, tsetse flies persist at lower densities in what might appear to be unsuitable environments probably occupying microclimatic niches (Bourne et al., 2001; Terblanche et al., 2008; Ducheyne et al., 2009).

The effects of anthropogenic environmental changes on the epidemiology and impact of livestock trypanosomosis are largely driven by the degree with which the tsetse flies adapt to an environment where domestic animals are becoming increasingly important for their survival. These changes have been demonstrated in southern Africa where epidemiological studies have clearly revealed the effect of such anthropogenic changes on the impact of the disease on livestock and the appropriateness of particular control strategies (Van den Bossche, 2001).

3. Livestock trypanosomosis – variations on a theme

Tsetse flies infest about 10 million km^2 of the African continent and probably are the most important vectors threatening productivity of large numbers of livestock and the health of people. Although tsetse flies are the only cyclical vector of trypanosomes, the epidemiology of the disease can vary substantially between areas and within an area over time. The changes in the epidemiology are largely a result of human interference and the increasing importance of susceptible livestock species as host of tsetse flies and reservoir of trypanosomes (Fig. 1). This is reflected clearly in the way in which trypanosomosis affects livestock production.

3.1. Epidemic livestock trypanosomosis

The devastating effects of trypanosomosis on livestock production are very obvious in areas where susceptible livestock are introduced in a tsetse-infested zone or vice versa. In extensive areas of sub-Saharan Africa, large herds have been decimated as a result of the disease. A good example, in southern Africa, is the plateau of eastern Zambia where devastating livestock trypanosomosis epidemics occurred after game and tsetse were spreading out of the

Luangwa Valley South and East onto the plateau (Hall, 1910; Neave, 1911; Vail, 1977). Further North, the introduction of livestock in the tsetse-infested areas of the Rift Valley in Ethiopia, as a result of overgrazing in the tsetse-free highlands, has resulted in important trypanosomosis outbreaks and the decimation of large livestock populations (Slingenbergh, 1992).

Notwithstanding the importance and devastating impacts of these livestock trypanosomosis epidemics, they are probably more an exception than the rule. The reason for the epidemic nature of trypanosomosis, with high morbidity and high mortality, is attributed to the diversity in the trypanosome population (Morrison et al., 2009; Masumu et al., 2009). In *Trypanosoma congolense*, an important trypanosome species infecting livestock, this diversity is expressed partly in substantial variations in the trypanosome's virulence in susceptible hosts. Studies have shown that the fitness of trypanosomes in a tolerant or resistant host (such as most wildlife species) is very much associated with the parasite's ability to reproduce quickly and be present in the peripheral circulation in sufficient numbers to be picked up and transmitted by tsetse flies. In susceptible animals, such a high reproductive capacity causes high parasitaemias and pathology. Hence, trypanotolerant game animals could be considered important reservoirs of trypanosome strains that are highly virulent for livestock (Van den Bossche, unpublished results). Since the virulence of the trypanosome strains transmitted by tsetse flies is an important determinant of the impact of the infection on the health of the susceptible host, it seems that epidemics of trypanosomosis with devastating effect on the livestock population may be due largely to the presence of virulent trypanosome strains from wildlife reservoirs or a dominant sylvatic transmission cycle. Game animals can be important reservoirs of trypanosomes. A survey conducted in the KwaZulu-Natal Province of South Africa revealed that about 20% of the buffalo's in the Hluhluwe-iMmfolozi Park were infected with *T. congolense* (unpublished results). The reservoir role of game animals of pathogenic trypanosome species is reinforced by observations at game/livestock interfaces where livestock trypanosomosis often has an epidemic character with high morbidity and high mortality. It is thus not surprising that recent outbreaks of livestock trypanosomosis such as the one in the KwaZulu-Natal Province of South Africa are associated with the presence of game animals (Kappmeier et al., 1998).

3.2. Endemic livestock trypanosomosis

Notwithstanding the potential impacts on livestock and livestock production of epidemic trypanosomosis, this type of the disease is not often encountered. In many tsetse-infested livestock areas, trypanosomosis has an endemic character with high morbidity but rather low mortality. The creation of an endemic situation is largely the result of the increasing role of susceptible livestock as host of tsetse flies and reservoir of trypanosomes and the use of trypanocidal drugs by livestock keepers.

As a result of drug use and the high mortality rates in untreated animals infected with virulent strains, the likelihood that virulent strains persist in susceptible livestock of the domestic transmission cycle is relatively low. On the plateau area of the Eastern Province of Zambia, for example, only about 20% of the trypanosome strains isolated from cattle had a virulent phenotype (Masumu et al., 2006). Moreover, laboratory experiments indicated that the presence of an infection with a low virulent trypanosome strain offers protection against the deleterious effect of an infection with a virulent strain (Masumu et al., 2009). This is the case on the plateau area of the Eastern Province of Zambia, and probably elsewhere in tsetse-infested Africa, where livestock has become the main reservoir host and where livestock trypanosomosis has become endemic with high morbidity but low mortality (Simukoko et al., 2007a; Marcotty et al., 2008). It thus seems that the domestication of the trypanosome transmission cycle has important repercussions for the impact of the disease on the health of livestock with the disease changing from a disease with an epidemic character (high morbidity and high mortality) to a disease with a rather endemic character (with high morbidity but low mortality).

4. To control or not to control – that is the question

4.1. Livestock trypanosomosis control in endemic areas

Although endemicity in trypanosomosis may be a new concept, there is ample evidence of areas where large numbers of livestock are kept in tsetse-infested zones and, in the absence of well-organised control campaigns, survive despite regular infections with trypanosomes. Irrespective of the fact that productivity in these areas is far from optimal it seems that a balance has been created between the susceptible host, the parasite and the control interventions applied often based entirely on irregular trypanocide applications to animals that are suspected to be infected with trypanosomes. This "living with disease" is facilitated by the dominance of trypanosome strains of low virulence circulating in the livestock population and offering a level of protection. In the livestock rearing areas of the plateau of eastern Zambia, for example, the prevalence of livestock trypanosomosis is about 30% but trypanocidal drug use is rather low with mainly curative treatments given to cows and oxen (Marcotty et al., 2008; Van den Bossche et al., 2000a). Although trypanocidal drug use practices can be improved, the infrequent use of trypanocides that are readily available and reasonably cheap is probably a good reflection of the perception of the impact of the disease on livestock health in the prevailing livestock production system (Delespaux et al., 2002; Van den Bossche et al., 2000a). Moreover, trypanosomosis challenge in cattle is heterogenous with large animals (e.g. oxen) contributing most to the overall incidence of infections in a herd (Simukoko et al., 2007b; Torr et al., 2007a). Heterogeneity of incidence or individual variation in exposure to vector-borne diseases is a well-known phenomenon and may have implications for the optimal design of disease control programs (Kelly, 2001; Woolhouse et al., 1997). The high risk of trypanosomal infection in oxen and the high proportion of oxen in the cattle herd in areas such as the eastern plateau of Zambia, make oxen the most appropriate part of the herd for prophylactic treatment with trypanocidal drugs. Such targeted drug campaigns will affect the most infected part of the herd and protects the most valuable part of the herd in the mixed-crop livestock production system. In addition, reducing the trypanocidal drug use frequency is likely to reduce the risk of further resistance development in trypanosomes.

The development of resistance in trypanosomes to the available trypanocidal drugs is considered an important constraint to the sustainability of a drug-based control strategy. On the plateau area of the Eastern Province of Zambia, the prevalence of trypanosome strains that have become resistant is high and increasing (Delespaux et al., 2008a,b). Development of resistance in trypanosomes is probably unavoidable but its development could be retarded by implementing good drug use practices (Geerts et al., 2001). Once present, trypanocidal drug resistance can be controlled when resistance to a single drug is present (sanative pair). The situation will be difficult to reverse in the case of multi-drug resistant strains. Notwithstanding the alarming rate at which trypanocidal drug resistance is spreading and the regular isolation in the field of trypanosome strains that survive any treatment even at very high doses, the actual impact of trypanocidal drug resistance on livestock and livestock production in trypanosomosis endemic areas is not known. Contrary to well-controlled experimental situations where the susceptibility of single trypanosome strains to trypanocidal drugs is tested, field situations are different. Similarly to the disease in livestock itself, concerted efforts should be made to clarify the epidemiology and impact of trypanocidal drug resistance before making generalized statements of its importance in subsistence livestock production systems. Drug pressure is undoubtedly a major contributing factor to the appearance and spread of drug resistance. An interesting strategy, in trypanosomosis endemic areas, could consist of limiting trypanocidal drug administration to anaemic animals. The criterion for drug administration should thus be a simultaneous presence of anaemia and trypanosomes. Intuitively, livestock keepers in trypanosomosis endemic areas already follow this simple guideline by mainly treating sick animals resulting in limited drug use (Van den Bossche et al., 2000a).

The choice of a control method or combinations of methods is determined largely by the strategy's effectiveness and its sustainability (Torr et al., 2005). The control and, ultimately, eradication of tsetse flies from the endemic areas offers the ultimate and probably the only solution for the trypanosomosis problem when increased livestock productivity is envisaged. However, the problems associated with sustaining vector control programs are well known (Torr et al., 2005). Temporal tsetse control operations could have deleterious effects on the existing balance between host/parasite and vector or the trypanosomosis endemicity. Tsetse control could be on option when reinvasion from surrounding areas is addressed adequately (i.e. natural or artificial barriers) or serious long-term commitments are made to sustain the control intervention. Since domestic animals are the primary source of food for tsetse, the application of insecticides to livestock (or selected animals in the herd) can be considered the most appropriate control method and has proven to be very effective in trypanosomosis endemic areas (Van den Bossche et al., 2004). Precautions should be taken to avoid destruction of endemic stability against some tick-borne diseases if present (Van den Bossche and Mudenge, 1999). The selective and restricted application of insecticides could reduce the overall coverage and minimise such unwanted side effects (Torr et al., 2007b).

4.2. *Livestock trypanosomosis control in epidemic areas*

The nature of epidemic trypanosomosis and its severe impact on livestock health requires swift action. Left untreated, the disease in livestock is likely to cause high mortality. This has been observed in Mozambique were trypanosomosis was a major constraint to the restocking of cattle after the civil war (Sigauque et al., 2000). The use of curative trypanocides offers a quick relief for the most severe trypanosomosis cases and prophylactic drugs may, in the absence of tsetse control, be an effective way of dealing with the problem. It could be argued that this approach, through large-scale use of prophylactic drug campaigns, has allowed for the exploitation of extensive tsetse-infested wild areas in many countries of southern Africa. In eastern Zambia, for example, the control of bovine trypanosomosis has relied heavily on the use of chemoprophylaxis and chemotherapy. Three-monthly block-treatment with prophylactic drugs was initiated in the mid-1960s and lasted until 1979 (Leak, 1980). However, the administration of such campaigns was and still is fraught with difficulties with lack of transport and frequent shortages of drugs resulting in prolonged treatment intervals. Although it is difficult to prove, it is very likely that the regular use of trypanocidal drugs, the gradual disappearance of game animals from the eastern plateau as a result of increased human population pressure and the increasing density of livestock and their role as host of tsetse and reservoir of trypanosomes have resulted in the endemic situation as it exists now. It is plausible that creating such endemicity could be one of the long-term strategies to manage livestock trypanosomosis in subsistence livestock production systems.

Although endemicity can be reached in areas where the role of wildlife as host of tsetse and reservoir of trypanosomes is decreasing, this is not possible in areas where game and livestock co-exist or at game/livestock interfaces. Here tsetse often have almost disappeared from the livestock production areas but livestock is still challenged at the edge of the tsetse-infested protected area. This is the case in large parts of Malawi (Van den Bossche et al., 2000b). Although the proportion of wild areas has reduced substantially over the past century, the current drive for reforestation, and the development and establishment of large trans-boundary conservation areas will create important reservoirs of tsetse flies that can transmit (often virulent) trypanosomes to susceptible livestock. As a result, the management of livestock trypanosomosis at game/livestock interfaces is becoming increasingly important. However, the presence of a protected tsetse-infested game area does not necessarily result in severe problems with livestock trypanosomosis in adjacent livestock production areas. In Malawi, for example, tsetse flies in the

Nkhotakota Game Reserve are concentrated deep inside the park resulting in minimal challenge of livestock kept at the park's edge (Gondwe et al., 2009). Nevertheless, it is likely that many of the future issues related to livestock trypanosomosis control will be associated with the control of the problem at such game/livestock interfaces. Although the use of trypanocidal drugs can offer a relief, endemicity will not be reached because of the continuous presence of the wildlife reservoir. Hence, reducing tsetse density at the edge of the protected area and reducing trypanosomosis challenge of livestock kept at the interface offer a solution. Here the treatment of livestock with insecticides is unlikely to be effective. Such treatments may reduce the density of the tsetse population present at the edges or just outside the park but will have little impact on the overall density of tsetse flies inside the protected area. Hence, stationary baits such as insecticide-treated targets that act as barriers will effectively prevent tsetse from reaching the edges of the infested area and challenge the livestock (Muzari, 1999). Such target-barriers have, for example, been very effective in controlling livestock trypanosomosis at the edge of the Kasungu National Park in Malawi (Van den Bossche and Vale, 2000).

5. Conclusion

Preconceived notions and unsubstantiated assumptions about livestock trypanosomosis and the perceived need for intervention are common. In addition, impatience because of slow progress in the control of tsetse-transmitted trypanosomosis has led some people to believe that a planning phase is unnecessary and often inappropriate strategies are adapted with limited long-term success. Finally, professional interests often guide control strategies losing sight of what realistically could be done and what is really required.

Notwithstanding the drive for area-wide control, reality shows that in most tsetse-infested areas the control of the disease is local and supported by limited resources. Livestock owners currently contribute significantly to trypanosomosis control by administering about 35,000,000 doses of trypanocides annually (Geerts et al., 2001).

In southern Africa, and probably elsewhere in the tsetse-infested parts of the continent, evaluation of the trypanosomosis situation reveals that the impact of the disease on livestock health and production varies substantially. Two different situations, i.e. endemic and epidemic, can be distinguished with important repercussions for the impact of the disease in livestock and its control. Notwithstanding the presence of trypanocidal drug resistance in endemic areas, the need for drastic interventions should be questioned. In this regard, the real impact of trypanocidal drug resistance and treatment failures on livestock health should be determined under field conditions and the possibility of "living with the disease" under the prevailing livestock production systems assessed.

Since most problems associated with livestock trypanosomosis are expected at game/livestock interfaces where the disease has an epidemic nature, more attention should be paid to developing appropriate control strategies for such situations.

Conflict of interest

The authors declare that there is no conflict of interest.

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