

Minireview paper**Parasitic zoonoses from dogs: how common are they in Zambia****ABSTRACT**

Zoonotic parasitic diseases including helminths and protozoa are common especially in areas with poor living conditions in developing countries. The poor living conditions combined with poor veterinary services and lack of awareness of the zoonotic diseases exacerbates the risks of disease transmission from animals to humans. Dogs serve different purposes, offering several benefits to humans, including companionship, life-saving actions, security as well as hunting and farming. However, dogs have also served as a link for parasite exchange among domestic livestock, wildlife and humans, and remain an important source of infectious diseases. The close relationship between dogs and humans and the fact that dogs live in close proximity to humans makes it possible to maintain the transmission cycle of parasites. This review gives an update on the occurrence of some zoonotic infections (*Cryptosporidium*, *Giardia*, *Trypanosoma* spp and helminthes) from dogs in Zambia and highlights the need for epidemiological studies to understand the exact role dogs play in these infections. Information generated from these studies; and awareness and knowledge of these zoonotic diseases by communities will assist in preventing such infections.

Key words: Zoonoses, dogs, *Cryptosporidium*, *Giardia*, Trypanosomes, helminths, Zambia

1. INTRODUCTION

In almost all human societies, dogs are widely used for different purposes, offering several benefits to humans, including companionship, life-saving actions, security as well as hunting and farming ([1-2]. The royalty of the dogs to man has earned them the name “man’s best friend”. In terms of companionship, dogs, in some homes, replace children who have grown and moved away from home [3]. From a public health perspective, however, dogs have been sources of zoonotic parasites [4-5]. Dogs have also served as a link for parasite exchange among domestic livestock, wildlife and humans, and remain an important source of emerging

and re-emerging infectious diseases [6]. The importance of dogs in zoonotic diseases is related to the fact that dogs live in close proximity to humans and are therefore able to maintain the transmission cycle of these parasites.

Dogs are hosts to many parasites that may be transmitted to humans through direct contact with infected animals or exposure to environments contaminated with infected dog faeces. A close contact between dogs and people increases the risk of transmission. Children are often at greatest risk of infections especially intestinal ones because of their play habits and affection for pets. Due to increased urbanization, the presence of pets especially dogs within houses has also increased in popularity [7]. In these urban settings, dog faeces represent an important environmental contaminant as they are not regularly removed. Moreover, vehicular traffic, as well as the wind, can facilitate spread viable pathogens present in the dog faeces, resulting in contamination of food and/or water which may later be a source of infection for humans.

Additionally, parasite eggs can also be carried into human houses if adhered to shoes or animals' paws [8-9]. Other environmental factors, such as the rain, may also play an important role in the transmission of these pathogens [10].

In Zambia, not many studies have been conducted to determine occurrence of the most zoonotic infections that are known to be transmissible to humans [5, 11-12] with very few on parasitic infections. The country has seen an increase in urbanization and keeping of dogs for security as well as pets. Information and knowledge on the occurrence and prevalence of zoonotic infections is important for communities to be well informed and for policy makers to have appropriate intervention measures. This review focuses on common parasitic zoonotic infections (helminths and protozoa) in dogs and their prevalence in dog populations in Zambia.

2. *CRYPTOSPORIDIUM* spp.

Cryptosporidium species are apicomplexan, protozoan parasites that infects the gastrointestinal tract of a wide range of vertebrates, including humans [13-14]. They are transmitted via the faecal-oral route by environmentally resistant oocysts that are shed in the faeces, contaminating

soil and water, and thus, providing multiple routes into the food chain [15]. *Cryptosporidium* spp. are common parasites of humans, domestic animals and wild vertebrates. Cryptosporidiosis, the disease caused by *Cryptosporidium* spp. has been considered to be a zoonotic disease for some time due to the wide host range [16].

Important *Cryptosporidium* species include *Cryptosporidium parvum* mainly in young calves (<30 days) *C. bovis* (older calves) and *C. andersoni* in adult cattle, *C. suis* in pigs, *C. felis* in cats, *C. wrairi* in guinea pigs, *C. meleagridis* and *C. baileyi* in birds, and *C. muris* in reptiles. Amongst these *Cryptosporidium* species, *C. parvum* stands out as the most “important” zoonotic species as it has been reported in humans in many countries in addition to being common in other domestic animals. *Cryptosporidium canis* has been isolated primarily in dogs, with occasional reports in humans [17-18]. Other zoonotic species include, *C. suis*, *C. felis* *C. canis*, *meleagridis* and *C. muris*, occurring occasionally especially in immunocompromised individuals. Despite the many reports of *C. canis* in dogs in many countries worldwide [19-21], there is no information on its presence in dogs in Zambia. Only one study is known to have been conducted in domestic dogs to determine the occurrence of *Cryptosporidium* spp and other parasites but no *Cryptosporidium* oocysts were detected in the 20 dogs that were tested [22]. Even if the role of dogs in the transmission of human cryptosporidiosis appears to be insignificant as evidenced in the studies in the United States [23], Guinea-Bissau [24]; and Indonesia [25], the canines appear to be linked to some zoonotic transmission of the parasite in both the developed and developing countries. Reports of human infections have been made in England, Wales, USA, Thailand, Kenya, Venezuela and Peru among others [17, 26-30]. It is therefore important to consider dogs as possible sources of *Cryptosporidium* infection even if information regarding the role of companion animals in the transmission of *Cryptosporidium* species is generally insufficient especially in immunocompetent individuals. In Zambia, a number of studies have reported *Cryptosporidium* infections in humans [31-33] but genotypes isolated from these are not known.

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80 **3. GIARDIA**

81 *Giardia duodenalis* (synonyms *Giardia lamblia*, *Giardia intestinalis*) is a protozoan parasite that
 82 infects the intestinal tract of many animal species including humans. Environmentally resistant
 83 cysts are passed in the faeces of infected animals, and are immediately infective if ingested by
 84 other susceptible hosts [34-35]. As such, *Giardia* species have been considered zoonotic
 85 probably because similar organisms infect humans and a variety of mammals and birds [36].
 86 However, evidence of the exact role of animals in the transmission of giardiasis is still limited.
 87 There are currently seven genotypic assemblages (assemblages A to F), which are distinct
 88 evolutionary lineages, as defined by phylogenetic analysis and enzyme electrophoresis [16,37].
 89 Assemblage A and B are considered to be predominantly for humans while C and D make up
 90 the majority of isolates from dogs. Assemblage E is isolated from hooved animals. Cats are
 91 hosts of Assemblage F while rats are hosts for Assemblage G [38-39]. Given the distribution of
 92 the assemblages between different animal species and humans, the zoonotic transmission of
 93 *Giardia* has been a topic of debate for a long time. Even if dogs appear to harbour only the
 94 canine oriented assemblage C and D, some studies have reported zoonotic forms in pet dogs. A
 95 study in the United States reported that 28% and 41% of client-owned dogs presenting with
 96 giardiasis to veterinary clinics in the western United States had potentially zoonotic
 97 assemblages A and B, respectively, while 15% and 16% had host specific assemblages C and
 98 D, respectively [40]. This data suggest the possibility the potential for transmission of non-
 99 canine-specific assemblages from owners to their dogs as well as zoonotic transmission from
 100 dogs to humans.

101 There is very little information on *Giardia* in animals in Zambia. A single study by Asha et al.
 102 [41] reported the presence of *G. duodenalis* in the African painted dog (*Lycaon pictus*) with both
 103 canine specific assemblages C and D as well as the zoonotic assemblages A and B being
 104 reported. The zoonotic assemblages were more common compared to the canine host specific

C and D, suggesting that these two assemblages have the potential for zoonotic transmission from the captive animals to humans due to close interaction. One study in domestic animals reported *Giardia* prevalence of 5% in domestic dogs [22]. Even though dogs may suffer minimal consequences of the disease, except in young puppies that may develop complications of persistent infection, impairment of growth and development [34,42], humans that acquire *Giardia* infections may develop intermittent diarrhoea associated with chronic infections [43]. The many reports of possible zoonotic transmission of *Giardia* from dogs to humans [40,44-46] stresses the need for further insight into the exact role of domestic animals in the transmission of this parasite.

4. *TRYPANOSOMA SPECIES*

In tsetse-infested sub-Saharan African countries, pathogenic protozoan trypanosome species are commonly transmitted to a wide range of susceptible mammalian hosts, including dogs. Transmission is through the infective tsetse fly (*Glossina* spp.) bites when taking a blood meal [47]. Dogs are specifically affected by *Trypanosoma evansi*, *Trypanosoma congolense*, and *Trypanosoma brucei brucei* [48] causing Canine African Trypanosomosis (CAT) with varying clinical presentation depending on species. In exotic breeds of dogs, *T. brucei* subspecies tend to cause acute disease [12] while infections due to *T. congolense* appear to be more chronic [12,49]. On the other hand, indigenous dog breeds appear to be more trypanotolerant and do not exhibit any clinical signs [47]. These trypanotolerant dogs therefore may act as sources of infection for other animals as well as humans. Dogs that harbour the human infective *T. brucei rhodesiense* and *T. brucei gambiense* and are usually asymptomatic but may serve as “an unknown” sources of infection for humans [50-51]. Although trypanosomosis is commonly reported in farm animals [52-53], Canine African trypanosomosis (CAT) is less frequently reported [49,54]. However, recent studies have actually indicated the significance of the trypanosome parasite in dogs. Affected animals that become clinically ill exhibit clinical signs that maybe severe, including lymphadenopathy, oedematous

forelimbs, distended abdomen, bilateral corneal opacity, conjunctivitis with mucopurulent discharge, pyrexia, dyspnoea and evidence of anaemia [12,55] with death occurring in some cases.

In Zambia, the first case of *rhodesianse* Human African Trypanosomiasis (rHAT) was first reported in 1910 by Stephens and Fantham [56] in the then northern Rhodesia. Since then, a number of cases have been reported; some documented [57-59] while others are not. Most of the cases have been related to some national parks in the eastern and northern parts of the country [59]. At risk are people that cohabit with wildlife in game management areas and tourists that visit national parks. With the available data indicating the presence of the infection in humans and the occurrence of the human infective parasites in “man’s best friend” [12,60], mechanisms to prevent transmission of trypanosomes in both animals and humans are necessary and cannot be over emphasized.

5. HELMINTHS

Helminths impede the successful rearing of dogs. The outcome of infection is lowered resistance to infectious diseases, retarded growth, reduced work/activity and feed efficiency and general ill-health [61]. Parasitized animals show a variety of symptoms, depending on the parasite species and density. These signs are attributable to intestinal obstruction, irritation, mal-digestion, malabsorbtion, and protein losing enteropathies [62]. Some of these helminths are of public health importance as zoonotic transmission can occur.

5.1 *Toxocara canis*

Toxocara canis, a cause of toxocariasis, is a common roundworm of dogs and infection occurs transplacentally, transmammmary and through ingestion of an infected paratenic host such as slugs. Infection may also occur through ingestion of eggs containing the infective second stage larvae (L2) from the environment [61,63]. Humans get infected by accidentally ingesting *Toxocara* eggs through soil contaminated with *Toxocara* eggs. In rare cases, infection has also been reported to occur by eating undercooked or raw meat.

Toxocariasis is one of the most common zoonotic infections and has been reported worldwide [64-66]. Infection in humans causes larva migrans syndromes (visceral and ocular larva migrans and covert toxocariasis) [67-68]. Initially only visceral and larval migrans were reported but it is now known that a syndrome known as covert toxoscariasis, characterised by abdominal pain, does occur in humans [67]. However, most human infections are usually asymptomatic, though some individuals may develop systemic disease or localised symptoms confined to the eye resulting in partial or complete blindness [69] (Despommier, 2003). The severity and type of disease in humans depend on how many larvae are ingested or number of migrating larvae, the frequency of re-infection, and the age of the host [64,69].

In Zambia, *T. canis* has been reported in domestic dogs several times [5, 70-71] with varying prevalence. However, it is not known whether human infections are there because there are no reports or documentation available. Nevertheless, there are reports of *Toxocara* infections in humans in some southern African countries. Recently, Liao et al. [66] reported 44.6% seroprevalence of *T. canis* in children in Swaziland, highlighting the occurrence of zoonotic infection. Presence of a dog in a household has been reported as the most important risk factor associated with human toxoscariasis. The increased urbanization in Zambia has come with an increase in the keeping of dogs for both security and as pets, which may come with a risk of possible zoonotic transmission of *Toxocara* and other helminthes if preventive measures are not put in place [6]. Apart from having a dog in the household, pica and geophagy are also important factors that can significantly contribute to infection especially in heavily contaminated areas [72].

5.2 *Ancylostoma caninum*

Infections with *A. caninum* remain common in dogs, with the high prevalences being reported world-wide [71,73-75]. Dogs acquire the infection through skin penetration at hair follicles or sweat glands, especially between the footpads where contact with soil is frequent; and through direct ingestion of the larvae. Clinical consequences include unthriftiness and chronic anaemia in

debilitated and malnourished animals; the anaemia of which can be fatal in young puppies [61]. Anorexia, weakness and emaciation usually accompany chronic disease. Diarrhoea with dark, tarry faeces is seen severe infections. Mature, well-nourished dogs are usually asymptomatic but act as a direct or indirect source of infection for puppies [39]. Development of clinical disease depends on the magnitude of the challenge and host factors.

Humans acquire *A. caninum* infection through contact with moist/wet sand soil containing filariform larvae from the faeces of dogs. This usually occurs in areas where there is heavy soil contamination such as densely populated areas with unsecured or free roaming dogs. Larval invasion of skin in humans produces pruritic papules [76]. Zoonotic infection with *A. caninum* may also occur through ingestion of the larvae in soil or in tissues of paratenic hosts. This may result in enteric disease known as eosinophilic enteritis [73, 77]. Infections may also lead to cutaneous larval migrans (CLM) which may be self-limiting or cause creeping eruptions which may persist for several months [78-79].

Ancylostoma caninum infections are very common in dogs in Zambia [70-71]. The amount of disease in people is unknown and this could be due to the fact that infections are either not documented or are not there. However, human infections with *A. caninum* have been reported elsewhere [77]. *Ancylostoma braziliense* is reported to be more frequently involved in CLM than *A. caninum* [39] but *A. caninum*, or *Uncinaria stenocephala* are also important causes [79].

5.3 *Dipylidium caninum*

Dipylidium caninum is a zoonotic tapeworm infection which is acquired from dogs when a person accidentally ingests a flea carrying the larval stage of the tapeworm. Infection is especially common in young children (< six months) who exhibit symptoms of diarrhoea and pruritus [80-82]. Infection has a characteristic feature of passage of proglottids in faeces in both dogs and infected children, though it is usually asymptomatic [80]. Additionally dogs tend to scoot to relieve the anal pruritus associated with the infection [83].

A number of studies have reported the presence of *D. caninum* in dogs in Zambia [5, 70-71].

Given the fact that infants are mostly infected in human infections, epidemiological studies are needed to determine the risk *D. caninum* dog infections pose to humans in Zambia.

5.4 *Echinococcus* species

Echinococcus species are parasitic trematodes that affect a number of animal species.

Echinococcus granulosus and *E. multilocularis* are of veterinary and public health importance [84]. Although the geographical distribution of *E. granulosus* is considered worldwide, it is higher especially in rural communities in developing countries [85]. Clinically, there are three broad morphological forms of echinococcosis that are recognized: cystic echinococcosis caused by *E. granulosus*, alveolar echinococcosis (*E. multilocularis*) and polycystic echinococcosis (*E. vogeli* and *E. oligathrus*) [86-87]. The *E. granulosus* “sheep” strain (G I) is generally considered as the most widespread strain worldwide and the common cause of cystic echinococcosis in humans [88]. This strain of *Echinococcus* is endemic in Africa [39, 89].

In dogs, *E. granulosus* infection is transmitted through ingestion of contaminated food through scavenging or when fed infected offals [90] (<http://www.oie.int/doc/ged/D13941.PDF>). The disease in dogs causes very minimal effects and is usually asymptomatic. In Zambia, *E. granulosus* has been reported in domestic animals [91-92], an indication that the parasite maybe present in most villages/areas in Zambia where livestock rearing is common. Pandey and Sharma [93] and Banda et al. [92] reported presence of hydatidosis in cattle from abattoirs in Lusaka and Western provinces, respectively. There is however, very little information available on echicoccosis in dogs. Only two studies have reported the presence of *E. granulosus* in dogs [5,70] and only one in humans [92], reporting a prevalence of 0.009%.

These reports of *Echinococcus* infections in dogs in Zambia [5, 70], though few, are important because of the role dogs play in human infection especially in rural communities where there is close contact with dogs as well as in other risk groups which include animal handlers, veterinarians, and dog owners [94]. Dogs shed eggs in the environment which can easily

contaminate fruits, vegetables or water, or can stick to the fur of dog. The eggs can be transferred from the dog to hands and to the mouth. The clinical consequences of *E. granulosus* infection may be severe with infected tissue (mostly lungs and liver) becoming fibrotic, in addition to other complications such as jaundice, fever, abdominal pain, hepatomegally, portal hypertension and cholangitis [94-95]. The symptoms, however, depend on the location of the cyst develops, and the size and numbers of cysts or metacestode mass and immune status on the host [96].

6. CONCLUSION

Although the potential role of dogs as source of zoonotic infections to humans has been recognized as a significant public health problem, investigations on the prevalence of most parasite infections have not been extensively conducted in Zambia. There is little documentation and these are mostly in domestic animals. The documented data may also not be complete and does not give a clear picture of the situation in the country. There is need to have well-documented country and regional data to have a comprehensive sub-Saharan picture of these zoonotic parasitic diseases.

ETHICAL APPROVAL

Not applicable

REFERENCES

1. Beck AM. The Impact of the canine clean-up law: both dogs and people profit. Environ Sci Policy for Sustain Dev. 1979;21(8): 197 DOI:10.1080/00139157.1979.9931200
2. Szabova E, Juris P, Miterpakova M, Antolova D; Papajova I; Sefcikova H. Prevalence of important zoonotic parasites in dog populations from the Slovak Republic. Helminthologia. 2007;44:170–6.
3. Beck AM. The human-dog relationship: a tale of two species. In Macpherson CN, Meslin L FX, Wandeler AI, Editors. Dogs, zoonoses and public health ISBN0-85199-436-9 DOI10.1079/9780851994369.0001; 2000.

- 260 4. Dantas-Torres F: Canine vector-borne diseases in Brazil. *Parasit Vectors*. 2008;1:25.
- 261 5. Nonaka N, Nakamura S, Inoue T, Oku Y, Katakura K, Matsumoto J, et al.: Coprological
262 survey of alimentary tract parasites in dogs from Zambia and evaluation of a coproantigen
263 assay for canine echinococcosis. *Ann Trop Med Parasitol* 2011;105:521–30.
- 264 6. Cleaveland S, Laurenson MK, Taylor LH: Diseases of humans and their domestic mammals:
265 pathogen characteristics, host range and the risk of emergence. *Philos Trans R Soc Lond B*
266 *Biol Sci*. 2001;356:991-9.
- 267 7. Overgaauw PAM; van Zutphen L; Hoek D; Yaya FO; Roelfsema J; Pinelli E; et al. Zoonotic
268 parasites in faecal samples and fur from dogs and cats in The Netherlands. *Vet Parasitol*.
269 2009;163:115-122.
- 270 8. Tarsitano E, Greco G, Decaro N, Nicassio F, Lucente MS, Buonavoglia C, et al.
271 Environmental monitoring and analysis of faecal contamination in an urban setting in the city
272 of Bari (Apulia Region, Italy): Health and hygiene implications. *Int J Environ Res Public*
273 *Health*. 2010;7:3972-86.
- 274 9. Deplazes P, van Knapen F, Schweiger A, Overgaauw PAM. Role of pet dogs and cats in the
275 transmission of helminthic zoonoses in Europe, with a focus on echinococcosis and
276 toxocarosis. *Vet. Parasitol*. 2011;182:41–53.
- 277 10. Fayer R. *Cryptosporidium*: a water-borne zoonotic parasite. *Vet Parasitol*. 2004;126:37–56.
- 278 11. Munang'andu HM, Mweene AS, Siamudaala V, Muma JB, Matandiko W. Rabies status in
279 Zambia for the period 1985-2004. *Zoonoses Public Health*. 2011;58(1):21-7. doi:
280 10.1111/j.1863-2378.2010.01368.
- 281 12. Namangala B, Oparaocha E, Kajino K, Hayashida K, Moonga L. Inoue N, et al. Short
282 Report: preliminary investigation of trypanosomosis in exotic dog breeds from Zambia's
283 Luangwa and Zambezi Valleys using LAMP. *Am J Trop Med Hyg*. 2013;89(1):116–8
- 284 13. Xiao L, Ryan UM. Cryptosporidiosis: an update in molecular epidemiology. *Curr Opin Infect*
285 *Dis* 2004;17:483-90.

- 286 14. Cacciò SM, Thompson RC, McLauchlin J, Smith HV. Unravelling *Cryptosporidium* and
287 *Giardia* epidemiology. Trends in Parasitol. 2005; 21: 430-7.
- 288 15. Slifko TR, Smith HV, Rose JB. Emerging parasitic zoonoses associated with water and food.
289 Int J Parasitol 2000; 30:1379-93.
- 290 16. Feng Y, Xiao L. Zoonotic potential and molecular epidemiology of *Giardia* species and
291 giardiasis. Clin Microbiol Rev. 2011;24:110-40.
- 292 17. Xiao L, Zhou L, Santin M, Yang W, Fayer R. Distribution of *Cryptosporidium parvum*
293 subtypes in calves in eastern United States. Parasitol Res. 2007;100: 701-6.
- 294 18. European Scientific Counsel Companion Animal Parasites (ESCCAP). Control of intestinal
295 protozoa in dogs and cats. ESCCAP guideline 06. The Mews Studio, Portland Road
296 Malvern, Worcestershire, WR14 2TA, 2011.
- 297 19. Abou-Eisha AM, Abdel-Aal AA. Prevalence of some zoonotic parasites in dog faecal
298 deposits in Ismailia city. Assiut Vet Med J. 1995;33.
- 299 20. Causape AC, Quiñez J, Sánchez-Acedo C, del Cacho E. Prevalence of intestinal
300 parasites, including *Cryptosporidium parvum*, in dogs in Zaragoza city, Spain. Vet. Parasitol.
301 1996;67:161-7.
- 302 21. Samie A, Tsipa MA, Bessong P. The epidemiology of *Cryptosporidium* in cats and dogs in
303 the Thohoyandou region, South Africa. African J Microbiol Research. 2013;7(21):2510-2518.
- 304 22. Siwila J, Phiri IGK, Enemark HL, Nchito M, Olsen A. Occurrence of *Cryptosporidium* and
305 *Giardia* in domestic animals in peri-urban communities of Kafue district, Zambia. Tanzania
306 Vet J, 2013 28: (Special issue).
- 307 23. Glaser CA, Safrin S, Reingold A, Newman TB. Association between *Cryptosporidium*
308 infection and animal exposure in HIV-infected individuals. J. Acquir Immune Defic Syndr
309 Hum Retrovirol. 1998;17:79–82.

24. Molbak, K., P. Aaby, N. Hojlyng, and A. P. da Silva. Risk factors for *Cryptosporidium* diarrhea in early childhood: a case-control study from Guinea-Bissau, West Africa. *Am J Epidemiol.* 1994;139:734–40.
25. Katsumata TD, Hosea E, Wasito S, Kohno K, Hara P, Soeparto et al. Cryptosporidiosis in Indonesia: a hospital-based study and a community-based survey. *Am J Trop Med Hyg* 1998; 59:628–32.
26. Pieniazek NJ, Bornay-Llinares FJ, Slemenda SB, da Silva AJ, Moura IN, Arrowood MJ, et al. New *Cryptosporidium* genotypes in HIV-infected persons. *Emerg Infect Dis.* 1999;5:444-9.
27. McLauchlin J, Amar C, Pedraza-Diaz S, Nicholas GL. Molecular epidemiological analysis of *Cryptosporidium* spp in the United Kingdom. Results of genotyping *Cryptosporidium* spp in 1,705 faecal samples from humans and 105 faecal samples from livestock animals. *J Clin Microbiol*, 2000;38:3984-9.
28. Gatei W, Ashford RW, Beeching NJ, Kamwati SK, Greensill J, Hart CA. *Cryptosporidium muris* infection in an HIV-Infected adult, Kenya. *Emerg Infect Dis.* 2002;8: 204-6.
29. Cama VA, Bern C, Sulaiman IM, Gilman RH, Ticona E, Vivar A, et al. *Cryptosporidium* Species and Genotypes in HIV-Positive Patients in Lima, Peru. *J Eukaryotic Microbiol.* 2003;50(6):531-3.
30. Gatei W, Wamae CN, Mbae C, Waruru A, Mulinge E, Waithera T, et al. Cryptosporidiosis: prevalence, genotype analysis, and symptoms associated with infections in children in Kenya. *Am J Trop Med Hyg.* 2006;75:78-82.
31. Nchito M, Kelly P, Sianongo S, Luo NP, Feldman R, Farthing M, Baboo AS. Cryptosporidiosis in urban Zambian children: an analysis of risk factors. *Am J Trop Med Hyg.* 1998;59(3):435–7
32. Amadi B Mwiya M, Musuku J, Watuka A, Sianongo S, Ayoub A, Kelly P. Effect of nitazoxanide on morbidity and mortality in Zambian children with cryptosporidiosis: a randomised controlled trial. *The Lancet*; 2002;360(9343):1375–80.

- 336 33. Siwila J, Phiri I, Enemark H, Nchito M, Olsen A. Seasonal prevalence and incidence of
337 *Cryptosporidium* spp. and *Giardia duodenalis* and associated diarrhoea in children attending
338 pre-school in Kafue, Zambia. Trans R Soc Trop Med Hyg. 2011;105:102–8.
- 339 34. Thompson RCA. Giardiasis as a re-emerging infectious disease and its zoonotic potential.
340 Int J Parasitol. 2000;30:1259-67.
- 341 35. Coklin T, Farber J, Parrington L, Dixon B. Prevalence and molecular characterization of
342 *Giardia duodenalis* and *Cryptosporidium* species in dairy cattle in Ontario, Canada. Vet.
343 Parasitol. 2007;150, 297–305.
- 344 36. Thompson RC. The zoonotic significance and molecular epidemiology of *Giardia* and
345 giardiasis. Vet Parasitol 2004; 126:15-35.
- 346 37. Ballweber LR, Xiao L, Bowman DD, Kahn G, Cama VA. Giardiasis in dogs and cats: update
347 on epidemiology and public health significance. Trends Parasitol. 2010;26:180–9.
- 348 38. Hopkins RM, Meloni BP, Groth DM, Wetherall JD, Reynoldson JA, Thompson RCA.
349 Ribosomal RNA sequencing reveals differences between the genotypes of *Giardia*
350 isolates recovered from humans and dogs in the same locality. J Parasitol. 1997; 83:44.
- 351 39. Bowman DD. Georgis' parasitology for veterinarians. 9th edition. Saunders Elsevier. St Louis
352 Missouri 63146. 2009.
- 353 40. Covacin C, Aucoin DP, Elliot A, Thompson RC. Genotypic characterisation of *Giardia* from
354 domestic dogs in the USA. Vet Parasitol. 2011; 177: 28-32.
- 355 41. Asha A, Lymbery A, Lemon J, Vitali S, Thompson RCA. Molecular epidemiology of *Giardia*
356 *duodenalis* in an endangered carnivore – The African painted dog. Vet Parasitol. 2010;174:
357 206–12.
- 358 42. Farthing MJG. Giardiasis. In Gills H.M. Editors Protozoal diseases. Arnold Publishers, UK;
359 1999.
- 360 43. Garcia LS. Diagnostic medical Parasitology 5th edition. ASM Press, Washington, D.C; 2007.

44. van Keulen H, Macechko PT, Wade S, Schaaf S, Wallis PM, Erlandsen SL. Presence of human *Giardia* in domestic, farm and wild animals, and environmental samples suggests a zoonotic potential for giardiasis. *Vet. Parasitol.* 2002;108:97-107.
45. Traub RJ, Monis PT, Robertson ID, Irwin PJ, Mencke N, Thompson RCA. Epidemiological and molecular evidence supports the zoonotic transmission of *Giardia* among humans and dogs living in the same community. *Parasitol.* 2004;128:253–62.
46. Leonhard S, Pfister K, Beelitz P, Thompson RCA. The molecular characterisation of *Giardia* from dogs in southern Germany. *Vet Parasitol.* 2007;150:33–8.
47. Abenga JN, David K, Ezebuio COG, Lawani FAG. Observations on the tolerance of young dogs (puppies) to infection with *Trypanosoma congolense*. *Afr J Clin Exper Microbiol* 2005;6:28–33.
48. Eloy LJ, Lucheis SB. Canine trypanosomiasis: etiology of infection and implications for public health. *J Venom Anim Toxins incl Trop Dis.* 2009;15(4):589-611.
49. Gow AG, Simpson JW, Picozzi K. The first report of canine African trypanosomosis in the UK. *J Small Anim Pract.* 2007;48:658–61.
50. Uilenberg G: A field guide for the diagnosis, treatment and prevention of African animal trypanosomiasis (FAO). Roma, Italy; 1998.
51. Matete GO: Occurrence, clinical manifestation and the epidemiological implications of naturally occurring canine trypanosomosis in western Kenya. *Onderstepoort J Vet Res* 2003;70:317–23.
52. Gardiner PR, Assoku RKG, Whitelaw DD, Murray M. Haemorrhagic lesions resulting from *Trypanosoma vivax* infection in Ayrshire cattle. *Vet Parasitol* 1989;31 (2-3):187–97
53. Simukoko H Marcotty T, Phiri I, Geysen D, Vercruysse J, Van den Bossche P. The comparative role of cattle, goats and pigs in the epidemiology of livestock trypanosomiasis on the plateau of eastern Zambia. *Vet Parasitol* 2007;147(3-4):231-8.

- 386 54. Laohasinnarong D, Thekisoie OM, Malele I, Namangala B, Ishii A, Goto Y, et al.. Prevalence
387 of *Trypanosoma* sp. in cattle from Tanzania estimated by conventional PCR and loop-
388 mediated isothermal amplification (LAMP). Parasitol Res. 2011;109:1735-9.
- 389 55. Kaggwa E, Munyua WK, Mugeru GM. The pathogenicity of *Trypanosoma brucei brucei* in
390 dogs. Bull Anim Heal Prod Africa. 1984;82(1):360-8.
- 391 56. Stephens JWW, Fantham HB. On the peculiar morphology from a case of sleeping sickness
392 and the possibility of its being a New Species (*T rhodesiense*). Roy Soc Proc B. 1910; 8:
393 plate 6.
- 394 57. Buyst H: The epidemiology, clinical features, and treatment, and history of sleeping sickness
395 in the Northern edge of Luangwa fly belt. Med J Zambia. 1974;8:2-12.
- 396 58. Mwanakasale V, Songolo P, Babaniyi O, Simarro P. Clinical presentation of human African
397 trypanosomiasis in Zambia is linked to the existence of strains of *Trypanosoma brucei*
398 *rhodesiense* with varied virulence: two case reports. J Medical Case Reports 2014;8:53.
- 399 59. WHO. Report of the first WHO stakeholders meeting on *rhodesiense* human African
400 trypanosomiasis. Report of the first WHO stakeholders meeting on *rhodesiense* human
401 African trypanosomiasis. World Health Organisation, Geneva, 2015.
- 402 60. Lisulo M, Sugimoto C, Kajino K, Hayashida K, Mudenda M, Moonga L, et al.. Determination
403 of the prevalence of African trypanosome species in indigenous dogs of Mambwe district,
404 eastern Zambia, by loop mediated isothermal amplification. Parasit & Vectors. 2014;7:19.
- 405 61. Soulsby E JL. Helminths, Arthropods and Protozoa of Domesticated Animals. 7th edition,
406 Bailliere Tindall, London. 1982.
- 407 62. Dunn A. Veterinary helminthology, William Heinemann Medical Books Ltd, London. 1978.
- 408 63. Burke TM, Roberson EL. Prenatal and lactational transmission of *Toxocara canis* and
409 *Ancylostoma caninum*: Experimental infection of the bitch before pregnancy. Int J Parasitol.
410 1985; 15(1):71–75
- 411 64. Schantz PM. *Toxocara* larva migrans now. Am J Trop Med Hyg 1989;41(suppl 3):21-34.

- 412 65. Stewart JM, Cubillan LD, Cunningham ET Jr. Prevalence, clinical features, and causes of
413 vision loss among patients with ocular toxocariasis. *Retina* 2005;25:1005-13.
- 414 66. Liao CW, Sukati H, D'Lamini P, Chou CM, Liu YH, Huang YC, et al.. Seroprevalence of
415 *Toxocara canis* infection among children in Swaziland, southern Africa. *Ann Trop Med*
416 *Parasitol.* 2010; 104(1):73-80. doi: 10.1179/136485910X12607012373795.
- 417 67. Nathwani D, Laing RB, Currie PF. Covert toxocariasis-a cause of recurrent abdominal pain
418 in childhood. *Br J Clin Pract.* 1992;46(4):271.
- 419 68. Schantz PM. Larva migrans syndromes caused by *Toxocara* species and other helminths.
420 In: Gorbach SL, Bartlett JG, Blacklow NR, editors. *Infectious diseases*. 3rd ed. Philadelphia,
421 Pa: WB Saunders Co; 2004.
- 422 69. Despommier D. Toxocariasis: clinical aspects, epidemiology, medical ecology, and
423 molecular aspects. *Clin Microbiol Rev.* 2003;16(2) 265–72
- 424 70. Islam SAWM, Chizyuka HGB. Prevalence of helminth parasites of dogs in Lusaka, Zambia.
425 *Trop Anim Health and Prod.* 1983;15(4): 234-6.
- 426 71. Bwalya EC, Nalubamba KS, Hankanga C, Namangala B. Prevalence of canine
427 gastrointestinal helminths in urban Lusaka and rural Katete Districts of Zambia. *Prev Vet*
428 *Med.* 2011;100(3-4):252-5.
- 429 72. Won KY, Kruszon-Moran D, Schantz PM, Jones JL. National seroprevalence and risk
430 factors for zoonotic *Toxocara* spp. infection. *Am. J. Trop. Med. Hyg.* 2008;79(4): 552–7.
- 431 73. Croese J, Loukas A, Opdebeeck J, Prociv P. Occult enteric infection by *Ancylostoma*
432 *caninum*: a previously unrecognized zoonosis. *Gastroenterol.* 1994;106:3-12.
- 433 74. Oliveira-Sequeira TCG, Amarante AFT, Ferrari TB, Nunes LC. Prevalence of intestinal
434 parasites in dogs from São Paulo State, Brazil. *Vet Parasitol.* 2002;103(1–2, 3):19–27
- 435 75. Zewdu E, Semahegn Y, and Mekibib B. Prevalence of helminth parasites of dogs and
436 owners awareness about zoonotic parasites in Ambo town, central Ethiopia Ethiop. *Vet J.*
437 2010;14(2),17-30.

- 438 76. Davies HD, Sakuls P, Keystone JS. Creeping eruption. A review of clinical presentation and
439 management of 60 cases presenting to a tropical disease unit. Arch Dermatol.
440 1993;129:588-591.
- 441 77. Prociv P, Croese J. Human enteric infection with *Ancylostoma caninum*: hookworms
442 reappraised in the light of “new” zoonosis. Acta Trop. 1996;62:23.
- 443 78. Blackwell V, Vega-Lopez F. Cutaneous larva migrans: clinical features and management of
444 44 cases presenting in the returning traveller. Br J Dermatol 2001;145:434–7.
- 445 79. Jackson A, Heukelbach J, Calheiros CML, Soares VL, Harms G, Feldmeier H. A study in a
446 community in Brazil in which cutaneous larva migrans is endemic. Clin Infect Dis 2006;
447 43:e13–8.
- 448 80. Turner JA. (1962). Human dipylidiasis (dog tapeworm infection) in the United States. J
449 Pediatric. 1962;61(5):763–8
- 450 81. Reid CJD, Perry FM, Evans N. *Dipylidium caninum* in an infant. Eur J Pediatr.
451 1992;151:502–503.
- 452 82. Molina C, Ogburn J, Adegboyega P. Infection by *Dipylidium caninum* in an infant. Arch
453 Pathol Lab Med. 2003;127:e157-e159.
- 454 83. Saini VK, Gupta S, Rakesh AKRL, Latchumikanthan A. Diagnosis and therapeutic
455 management of *Dipylidium caninum* in dogs: a case report. J Parasit Dis DOI
456 10.1007/s12639-015-0706-9.
- 457 84. Eckert J, Deplazes P, Craig PS, Gemmell MA, Gottstein B, Heath D, et al. Echinococcosis in
458 animals: clinical aspects, diagnosis and treatment. In Eckert J, Gemmell MA, Meslin FX,
459 Pawlowski ZS. Editors. WHO/OIE Manual on echinococcosis in humans and animals: a
460 public health problem of global concern. World Organisation for Animal Health, Paris: WHO.
461 2001.
- 462 85. Eckert J, Deplazes P. Biological, epidemiological and clinical aspects of echinococcosis, a
463 zoonosis of increasing concern. Clin Microbiol Rev. 2004;17(1):107–35.

- 464 86. Khuroo MS. Hydatid disease: current status and recent advances. *Ann Saudi Med*,
465 2002;22(1-2): 56–64.
- 466 87. Raether W, Hänel H. Epidemiology, clinical manifestations and diagnosis of zoonotic
467 cestode infections: an update. *Parasitol Res*. 2003; 91(5): 412–438.
- 468 88. Thompson RCA, Lymbery AJ. Echinococcus: biology and strain variation. *Int J Parasitol*.
469 1990; 20(4): 457-70.
- 470 89. Magambo J, Njoroge E, Zeyhle E. Epidemiology and control of echinococcosis in sub-
471 Saharan Africa. *Parasitol Int*. 2006; 55(supplement): S193–S195.
- 472 90. <http://www.oie.int/doc/ged/D13941.PDF>. General information disease information sheet.
- 473 91. Macpherson CNL, Wachira TWM. Cystic echinococcosis in Africa south of the Sahara. In
474 Andersen FL, Ouhelli H, Kachani M. Editors. Compendium on cystic echinococcosis in
475 Africa and Middle Eastern Countries with special reference to Morocco. Provo: Brigham
476 Young University Print Services. 1997.
- 477 92. Banda F, Nalubamba KS, Muma JB, Munyeme M, Munang'andu HM. A cross-sectional
478 study investigating cystic hydatidosis in slaughtered cattle of Western Province in Zambia.
479 2013;Article ID 468163, 9 pages <http://dx.doi.org/10.5402/2013/468163>
- 480 93. Pandey GS, Sharma RN. A survey of pulmonary diseases at Lusaka abattoir in Zambia. *Bull*
481 *Anim Health Prod Africa*. 1987;35, 336-8.
- 482 94. Pawłowski ZS; Eckert J; Vuitton DA; Ammann RW; Kern P; Craig PS; et al. Echinococcosis
483 in humans: clinical aspects, diagnosis and treatment. In Eckert J, Gemmell MA, Meslin FX,
484 and Pawłowski ZS Editors. WHO/OIE manual on echinococcosis in humans and animals: a
485 public health problem of global concern. World Organisation for Animal Health, Paris: WHO;
486 2001.
- 487 95. Budke CM, Deplazes P, Torgerson PR. Global socioeconomic impact of cystic
488 echinococcosis. *Emerg InfectDis*. 2006;12:296-303.

- 489 96. Larrieu, EJ, Frider B. Human cystic echinococcosis: contributions to the natural history of the
490 disease. *Ann Trop Med Parasitol*. 2001;95:679-87.