



Companion Animals: A Potential Threat in Emergence and Transmission of Parasitic Zoonoses

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Abstract | Recent emergence of zoonotic-parasitic diseases in humans are due to evolution of microbes or parasites with alterations of host ranges, vector system, infectivity, virulence and/or re-occurrence of an unreported infection. Although, zoonotic parasitic diseases of companion animal origin are very familiar and deliberately studied in American and European countries, they are under prioritized areas of human health concern in developing countries like India. Circumstances prevailing in developing countries are favourable for easy and diffuse transmission and surfacing of zoonotic parasitic infections *viz.* toxoplasmosis, giardiasis, toxocarosis, echinococcosis, leishmaniasis, etc. However, with the implementations of personal hygiene and sanitary measures, appearance and spread of such zoonotic parasitic infections from companion animals can be prevented. Pet owners must be educated in a right way about the potential zoonotic risks, mode of transmission of these infections from their pets. It has been concluded that veterinarians need to play an immense role in educating and creating awareness on transmission and prevention of companion animal zoonoses in humans. This review discusses about the common parasitic zoonoses of companion animals. The primary focus of this review is mostly about canine and feline parasitic zoonoses that were the major threat in the developing nations.

Keywords | Companion animals, Zoonoses, Emergence, Parasitic infections, Transmission

Editor | Kuldeep Dhama, Indian Veterinary Research Institute, Uttar Pradesh, India.

Received | April 14, 2015; **Revised** | April 17, 2015; **Accepted** | September 18, 2015; **Published** | October 21, 2015

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Citation | Murugan MMS, Arunvikram K, Pavulraj S, Milton AAP, Sinha DK, Singh BR (2015). Companion animals: A potential threat in emergence and transmission of parasitic zoonoses. *Adv. Anim. Vet. Sci.* 3(11): 594-604.

DOI | <http://dx.doi.org/10.14737/journal.aavs/2015/3.11.594.604>

ISSN (Online) | 2307-8316; **ISSN (Print)** | 2309-3331

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INTRODUCTION

Pet animals play a significant role in societies all over the world. They are vital companions in numerous households, contributing to the social, physical, mental and emotional development of kids, and owners in particularly aged people (Zasloff, 1994; Jennings, 1997). They are considered as one of the family member in the home. When we know the benefits of the association between human and animals, we should also concern about the spread of diseases from them (Paul et al., 2010). Furthermore, pet owners stopover their physician less often, use less medication and have lesser blood pressure and cholesterol levels with cool mind than those do not have pets in their home (Headey, 1999). It has been documented that health risks *viz.*, bites of animals and skin-allergy are the common health associ-

ated risks with pets (Milton et al., 2015; Saminathan et al., 2015). But, various ranges of infections and infestations, including bacterial, viral, fungal and parasitic diseases, are in a way of being transmitted to humans from pets (Plant et al., 1996; Geffray, 1999). Zoonoses and diseases due to parasites are often underappreciated. It leads to diseases and cause may be managed inappropriately or gone undiagnosed (Paul et al., 2010). The possible health hazard to man due to GI parasites harbored by pet animals leaves a major crisis in different parts of the earth (Schantz, 1994). Zoonotic parasitic diseases spread to humans by ingestion of infectious intermediate stages *viz.* oocysts, cysts, spores, ova, larva or larval stages or by consumption of raw or undercooked meat with infective stages in tissues (Milton et al., 2015). Humans may act as final, intermediate, paratenic or accidental hosts in the life cycle of the parasite.

The common and rare parasitic zoonoses associated with companion animals and the agents causing the disease in humans are discussed in Table 1 and 2, respectively, and exotic companion animal parasitic zoonoses are discussed in Table 3.

PARASITIC ZOOSES IN INDIA

It has been predicted that more than 19.2 million mongrel dogs are there in India in spite of several control measures (WHO, 1996). Countries like India, unrestrained stray and semi-domesticated canine lives in close association with growing densities of humans in urban cities. Humans frequently have a close association with semi-domesticated canines in rural surroundings (Dutta, 2002). These

socio-economically underprivileged communities with the low levels of sanitation and hygiene, over-crowding ever growing population, deficient of veterinary attention and potential zoonotic awareness, aggravates the chances for zoonotic disease transmissions (Schantz, 1991). The surveillance and control of zoonotic diseases of canines in India is unprioritized in disparity to other human health harms with huge of morbidity, mortality and case fatality, like HIV/AIDS, malaria, tuberculosis and other childhood diseases (WHO, 2003). Common parasitic zoonoses viz. hydatid disease from canines (Bhandarkar and Talvarkar, 1973; Bhojraj and Shetty, 1999) and toxocariasis from felines (Mirdha and Khokar, 2002; Malla et al., 2002) are sporadic in nature. In spite of demonstrating strong endemicity of several parasitic zoonotic diseases (Table 1 and 2) from

Table 1: Common parasitic zoonoses from companion animals

Disease in companion animals	Parasitic zoonotic agent	Disease in humans	Diagnostic techniques	Prevalence	References
Echinococcosis	<i>Ecchinococcus granulosus</i>	Cystic echinococcosis	Histopathology	6-8% in small ruminants	Macpherson (2003); Romig et al. (2015); Khan et al. (2015)
	<i>Ecchinococcus multilocularis</i>	Alveolar echinococcosis	Microscopy, ELISA for coproantigen detection and copro-DNA detection by PCR	70%	Conraths and Deplazes (2015)
Toxoplasmosis	<i>Toxoplasma gondii</i>	Congenital and Ocular Toxoplasmosis	IgM and IgG ELISA	30-50% in organic free range farming	Dubey (2010); Tenter et al. (2000)
Toxacariasis	<i>Toxacara canis</i> , <i>Toxacara cati</i>	Visceral and Ocular Larval Migrans	ELISA with <i>Toxacara</i> spp. excretory-secretory (TES) antigen or Western blot, larva can be detected by ultrasound, computed tomography (CT) and magnetic resonance imaging (MRI)	2% to 44% in human, 3.5% to 34% in dogs, 8% to 76% in cats	Smith et al. (2009); Lee et al. (2010)
Ancylostomiasis	<i>Ancylostoma caninum</i>	Cutaneous Larval Migrans	Microscopy for faecal smear, PCR, PCR-RFLP, DNA sequencing	14% in dogs	Traub et al. (2008); Schantz (1999)
Giardiasis	<i>Giardia duodenalis</i>	GI disturbances	Microscopy for faecal smear (centrifugal sedimentation and centrifugal flotation)	70.5% in human	Almeida et al. (2015)
Cryptosporidiosis	<i>Cryptosporidium parvum</i>	Rare infection	Microscopy for faecal smear, DNA Sequencing, immunofluorescence antibody test, PCR		Forester et al. (2010)
Leishmaniasis	<i>Leishmania infantum</i>	Cutaneous and Visceral Leishmaniasis	Microscopy for faecal smear, indirect fluorescence antibody (IFA), enzyme-linked immunosorbent assay (ELISA) or western blot	42% in dogs	Molina et al. (1994); Sharma et al. (2003)
Dipylidiosis	<i>Dipylidium caninum</i>	Children are affected	Microscopy for faecal smear, enzyme-linked immunosorbent assay (ELISA) or western blot	16.63% in dogs	Zanzani et al. (2014)

Table 2: Rare parasitic zoonoses from companion animals

Disease	Country	Etiology	Vector / source	Diagnostic techniques	Prevalence	References
Babesiosis	USA	<i>Babesia canis</i> , <i>B.conrade</i>	<i>Ixodes ricinus</i>	Giemsa or Wright's stained blood smears, UV illumination after staining with acridine orange, serological tests, PCR		Johnson et al. (2009)
Chagas Disease (American trypanosomiasis)	USA	<i>Trypanosoma cruzi</i>	Triatomine bugs	Blood smears, serological tests, PCR, ELISA, IFA, immunochromatic tests	42% in dogs	Kjos et al. (2008)
Canine Heart worm	USA	<i>Dirofilaria immitis</i>	<i>Ctenocephalides canis</i>	Wet blood smear, Knott's method, PCR and DNA sequencing techniques	4-13% in dogs	Simon et al. (2012)
Paragonimiasis (Lung Fluke)	China	<i>Paragonimus westermanii</i>	Crabs, Cray fish	Microscopy of sputum smear, biopsy, pleural fluid, faecal egg. Intradermal (ID) test, complement fixation test (CFT), immunodiffusion, indirect haemagglutination test (IHA), enzyme-linked immunosorbent assay (ELISA), dot-ELISA, and Western blot	8.3% in cats	Xu et al. (2005); Liu et al. (2008)
Clonorchiasis	China	<i>Clonorchis sinensis</i>	Fish, shrimp	Microscopy for faecal smear, ultrasound examination, magnetic resonance imaging (MRI), tissue harmonic imaging (THI), immunological approaches, PCR and DNA sequencing		Qian et al. (2015)
Trichinosis	China	<i>Trichinella spiralis</i>	Dog meat	Microscopy for faecal smear, meat inspection, eosinophilia, and elevated creatinine kinase, biopsy, ELISA, DNA sequencing, PCR	7-40% in dogs	Zhou et al. (2008); Franco Sandoval et al. (2012)

Table 3: Exotic companion animal zoonoses

Species	Zoonotic parasitic disease	Diagnostic techniques	Reference
Rabbits	<i>Cheyletiella parasitivorax</i> (Mite)	Skin scrapping (flea comb and potassium hydroxide technique), skin biopsy	Frank et al. (2013)
Rats	<i>Hymenolepis diminuta</i> (cestode)	Microscopy of faecal egg smear, larval staining with Semichon's acetocarmin and counterstained with fast green	d'Ovidio et al. (2015)
Rodents	<i>Trixacarus caviae</i> (Acariasis)	Skin scrapping (Faure's method)	Singh et al. (2013)
Snakes	Pentostomiasis (<i>Armillifer armillatus</i>)	Microscopy of faecal egg smear, DNA Sequencing and PCR, histopathology	Hendrix and Blagburn (1988); Tappe et al. (2013)
Fish	Clonorchiasis, Diphyllbothriosis, Gnathostomiasis	Microscopy of faecal egg smear, DNA Sequencing and PCR, histopathology	Chai et al. (2005); Jongthawin et al. (2015); Rivero et al. (2015)

dogs, felines, rabbits, fishes, rodents, snakes (Table 3), etc. understanding, knowledge on pervasiveness of the risk factors allied with zoonotic parasites are fundamentally deficient.

RISK POTENTIAL OF PARASITIC ZOO NOTIC DISEASES

Potential zoonotic parasitic diseases spread by close interactions of pets with children, pregnant women and immunocompromised individuals (Juckett, 1997; Mani and Maguire, 2009). Efficient control of parasitic zoonoses

depends on complete understanding of life cycle of parasites, especially in infections where humans participate in perpetuating the transmission cycles (Thompson, 1999). For example, the threat of getting cerebral toxoplasmosis is not augmented by having a pet cat, in many case, infection occurred due to reactivation of latent infections due to consumption of undercooked meats (Frenkel, 1990). Risk of getting zoonotic infections in humans increased to several magnitude by occupational exposure particularly in veterinarians, pet owners, farmers, animal handlers, animal researchers, butchers, etc. (Kahn, 2006; Baker, 2009; Now-

MODES OF TRANSMISSION

Common modes of zoonotic transmission occurs through direct contact on skin and mucous membranes by animal bites, scratches, or contact with infected animal faeces, urine, saliva, other body fluids and fomites. Further, ingestion of food and water contaminated with faeces, inhalation of aerosolized infectious droplets, vectors and other invertebrates also a common mode of transmissions (Mani and Maguire, 2009).

MECHANICAL TRANSMITTERS OF HUMAN PARASITES

The role of the dog as a mechanical reservoir for human parasites were observed in tea-growing personnel in Assam, where parasitic stages which supposed to be host-specific for humans such as *Ascaris spp.*, *Trichuris trichiura*, *Hymenolepis diminuta* and *Isoospora belli* were detected in canine faeces (Traub et al., 2002). About 30% of *Ascaris* eggs were detected in canine faeces produced motile larvae when subjected 2 to 6 weeks after incubation at room temperature. Recently, Polymerase chain reactions based Restriction fragment length polymorphism method developed for identification of different species of *Ascaris* ova directly from canine faeces, revealed abundance of *Ascaris lumbricoides* in sampled canines which signifies the role of canines as a possible involuntary transmitter and disseminator of *Ascaris* to humans; it increases the contact of infective stages of parasitic eggs to human population (Traub et al., 2002). Mechanical transmission of zoonotic disease by dogs is the least ignored aspect in socio-economically underprivileged parts of Asia, South America, Australia and Africa (Sterneberg-van der Maaten et al., 2015).

HUMAN BEHAVIOUR AND EMERGENCE OF PARASITIC ZONOSSES

Omnipresent distribution of canines all over the world in forms of pet dogs, stray, mongrel and feral dogs, has a synanthropic relationship with human being, makes a significant role in transmission of zoonotic disease (Macpherson, 2005). Close human association with canine and felines due to companionship resulted in unwanted sharing of more than 60 parasitic species, viz. *Echinococcus spp.*, *Diphyllobothrium*, *Ancylostoma*, *Toxocara spp.*, *Giardia spp.*, *Cryptosporidium spp.* and *Toxoplasma spp.* (Sterneberg-van der Maaten et al., 2015).

Behavior of human beings towards pet dogs has significant role in the maintenance of parasitic infections due to cestode, mainly *Echinococcus granulosus*, which causes Cystic Echinococcosis (CE) and *Echinococcus multilocularis*

which causes Alveolar Echinococcosis (AE) (Macpherson et al., 2003). Canine are considered as definitive hosts for *E. multilocularis* (Thompson et al., 2003). In countries like India, where uncontrolled stray dogs intentionally fed offal of other animals results in higher incidence of *E. granulosus* (Macpherson et al., 1985). Developing countries do not have stringent dog population control programs and people also have dogs as pets (Akakpo, 1985; Conrath and Deplazes, 2015), but still, rearing of dogs as pet is of very small proportion (Dar and Alkarmi, 1997; Romiq et al., 2015).

CYSTIC AND ALVEOLAR ECHINOCOCCOSIS

Hydatid cysts - the larval stages of *E. granulosus* and is causal organism of cystic echinococcosis in humans (Eckert et al., 2000a). *E. granulosus* is a cestode, in its life cycle it has canine and other species of canids as final definitive. In some cases domestic and other wild ungulates may act as an intermediate hosts for larval stages of parasite (Thompson, 1995). Metacestode stage of *E. multilocularis* causes alveolar echinococcosis in humans (Khan et al., 2015). These parasites perpetuate in silvatic life cycle with wild foxes as final hosts and rodent act as intermediate hosts. The metacestode stage also called as echinococcal cyst characterized by spherical, fluid-filled, cyst, comprise of an inner germinal layer of cells supported by acellular, acidophilic-staining, laminated membrane of inconsistent thickness (Moro et al., 2008, Romig et al., 2015). Development of metacestode cysts observed in almost all anatomic sites of the body after ingestion of *E. granulosus* ova, but, cyst commonly observed in liver and lungs (Pawlowski, 1997; Eckert et al., 2000c). Distributions of *E. granulosus* have been reported in all over the world, irrespective of geographical limitations (Eckert, 2000b).

EMERGENCE AND TRANSMISSION OF CYSTIC ECHINOCOCCOSIS

Feeding of canines with sheep offal causes transmission of sheep strains to dogs and then to humans (Moro et al., 2008). Dogs infected with *Echinococcus* tapeworms excrete the ova in faeces and humans get infection by fecal-oral route of transmission. Further, parasitic ova may attach to hairs near the anal region of infected dogs, and also around muzzle and paws. Infection may also spread by contaminated water, food due to mechanical transmission of eggs in to it (Moro et al., 2009). Maximum occurrence of cystic echinococcosis in animals and humans are observed in temperate countries like, southern South America, Mediterranean littoral, central Asia, China, southern and central parts of the former Soviet Union, Australia and Africa (Yang et al., 2006; Moro and Schantz, 2006; Conrath and Deplazes, 2015).

EMERGENCE AND TRANSMISSION OF ALVEOLAR ECHINOCCOSIS

Infection of metacestode (larval) stage of *E. multilocularis* causes AE in humans (Conraths and Deplazes, 2015). Foxes and rodents act as definitive host and intermediate host for *E. multilocularis* respectively (McManus et al., 2003). Domestic canines and feline may get infection by eating infected wild rodents from wild. Encroachments of foxes from wild to urban and suburban areas increase the probability of getting infection to dogs (Eckert et al., 2004). Cats are less susceptible to infection than canines (Kapel et al., 2006). Close association of pet dogs with humans increase the risk of infection with AE. It has been well documented that dogs are considered as appropriate definitive hosts for *E. multilocularis* (Thompson et al., 2003). Parameters associated with emergence of *E. multilocularis* infection includes increased fox populations and prevalence of parasite, invasion of cities and villages by foxes and transmission of diseases in humans by dogs and cats (Eckert, 2000a).

TRANSMISSION OF TOXACARIASIS

The genus *Toxocara* contains two species, *Toxocara canis* and *Toxocara cati* which are widespread parasites of canines and felines, respectively. Transplacental transmission to puppies and trans-mammary transmission in kittens are the main route of infections. Canines and feline acquiring patent infection of *Toxocara spp.* at any age by ingestion of ova or paratenic hosts (Garden lizard). Clinical signs of infection include abdominal discomfort, diarrhea, emesis, stunted growth and intestinal obstruction in rare cases. Human infection occurs due to accidental ingestion of embryonated eggs from contaminated soil, water, food, fomites or by direct contact with infected dogs and cats (Smith et al., 2009) which may results in ocular larva migrans (OLMs), visceral larva migrans (VLMs), neurotoxocarosis, eosinophilic meningoencephalitis (EME) and covert toxocariasis (CT) (Finsterer and Auer, 2007; Rubinsky-Elefant et al., 2010). Cases of human larval toxocariasis are well documented with different signs of infection as described. Some manifestations may lead to enduring ocular or neurological damage, which emphasizing role for physician and veterinarians in educating the public community on modes of transmission of infection, populations at risk, and prevention and control measures (Lee et al., 2010).

DOG'S HAIR - POTENTIAL TRANSMITTER OF TOXACARA EGGS

Transmission mainly occurs by direct contact with dogs or by contaminated soils (Roddie et al., 2008). Wolfe and Wright (2003) proposed a hypothesis that humans may get infection by ingestion of embryonated eggs directly from hair coat of a dog (more than 20 Egg per gram of hair). It has been estimated that density of eggs in hairs is much

higher than eggs found in soil (Jacobs et al., 1977; Holland et al., 1991; O'Lorcain, 1994a). Roddie et al. (2008) reported that more than 67% of the canines were positive for *Toxocara* eggs in their hair coat, out of 82.4% of all the eggs recovered were viable and embryonated. Furthermore, 94% of embryonated eggs were seen on puppies and adult dog harbors few as 0.6% of embryonated eggs (Roddie et al., 2008).

The shorter hairs on puppies allow heat transfer to parasitic eggs and may be favourable environment for development of larvae in eggs. Numbers of worms in puppies also correlated with maximum intensities of eggs on the hair. All this suggests that pregnant bitches and puppies needs to be dewormed during the last weeks of pregnancy and first few weeks of age after whelping (Roddie et al., 2008).

TRANSMISSION OF TOXOPLASMOSIS

Toxoplasmosis is the most common zoonotic parasite throughout the world, caused by *Toxoplasma gondii* (Dubey, 2010). It is a facultative heteroxenous, polyxenous protozoan parasite. Transmitted by several route in different host species. Infective stages of parasite are *viz.* tachyzoites, bradyzoites seen in tissue cysts and sporozoites containing sporulated oocysts in it. Oocysts released form definitive host are highly infective to several non-feline mammalian hosts which indicating adaptations of parasite for fecal-oral transmission in these species including humans (Dubey, 2009). All three stages are infectious to both intermediate as well as definitive hosts. They get infection by ingestions of infectious oocysts from environment, ingestion of tissue cysts in raw or undercooked meat or offal of intermediate hosts, or by transplacental transmission of tachyzoites (Dubey, 1993; Dubey et al., 1998). Transmission may also take place by tachyzoites from blood products, unpasteurized milk and tissue transplants. Consumption of uncooked pork and mutton has been considered as a major route of transmission to human beings in past (Tenter et al., 2000).

TRANSMISSION THROUGH TISSUE CYSTS OF *T. GONDII*

Tissue cysts of *T. gondii* are considered as an important source of transmission to human beings. Tissue cysts are less resistant to environmental conditions whereas oocysts are relatively resistant to changes in temperature and maintain their infectivity even refrigerated at 4°C (Dubey et al., 1990). Tissue cysts may also survive at freezing temperatures (-8°C) for more than a week (Kotula et al., 1991). But, majority of tissue cysts are killed by freezing at -12°C. Certain strains of *T. gondii* may resistant to freezing (Kuticic and Wikerhauser, 1996). In contrast, tissue cyst in meat is normally killed by heating to 67°C (Tenter et al., 2000).

TOXOPLASMA OOCYSTS SURVIVAL AND TRANSMISSION IN ENVIRONMENT

Domestic feline and other feline species may be infected

with *T. gondii* by ingestion of infectious oocysts or tissue cyst. Infected cats shed huge numbers of oocysts (up to 100 million oocysts) after an initial infection with *T. gondii* (Dubey, 1996; Omata et al., 1990). Under optimal conditions like adequate humidity, aeration and warm climate, oocysts sporulate and become potentially infectious in 6 days (Dubey, 1986). Further, secondary shedding of oocysts may be induced in cats that challenged with *T. gondii* after 6 years of initial infection (Dubey 1995a; Dubey, 1995b). Sporulated oocysts of *T. gondii* are resistant to ambient conditions. They survive cold and resist dehydration and may remain infectious up to 18 months in soil or sand (Frenkel, 2000). Sporulated oocysts are impervious and very resistant to common disinfectants (Kuticic et al., 1996). Immunocompromised persons and pregnant women (high risk group) should maintain good hygienic habits. They should clean vegetables and fruits properly before consuming, which may contaminate with cat faeces (Tenter et al., 2000).

EMERGENCE OF GIARDIASIS

Giardia duodenalis is the widespread intestinal parasite of humans and mammals all over the world. It is a familiar and regular cause for sickness of human beings at several occasions. Epidemiology revealed that humans are the reservoir host for human giardiasis due to person to person direct transmission. But canines and felines carry this *Giardia* which may be infective to humans, thus considered with zoonotic potential in immunocompromised individuals (Robertson et al., 2000). Disease transmission mainly occurs by feco-oral route by ingestion of infective stage cysts tainted with food and water (Hunter and Thompson, 2005; Kasprzak et al., 1989; Batchelor et al., 2008). Eight common genetic groups have been reported out of which, A and B genotypes are observed in both animals and humans (Monis et al., 2009; Thompson and Monis, 2011; Thompson et al., 2008). Traub et al. (2004a) reported the prevalence of infection in tea estate personnel (up to 39 and 16% assemblage of B and A respectively) especially in Assam state of India. Similar findings are observed by Thompson (2004) while working with *Giardia* from humans and dogs, suggested that dogs got infection from human reservoir. Further, these enteric protozoan parasites are impassive to anthelmintics, which are at present use. These intracellular coccidian parasite may colonize the place vacated by other intestinal parasites like *D. caninum* and *T. canis* (Robertson et al., 2000).

OCCASIONAL ZONOTIC RISK FROM CRYPTOSPORIDIUM

Cryptosporidium spp., is the obligate intracellular coccidian parasite which mainly infect gastrointestinal tracts and

respiratory of a several hosts, especially lambs, calves, kids and piglets. *Cryptosporidium parvum* and *C. hominis* are the common coccidian parasites of humans and *C. canis* (canines) and *C. felis* (feline) are less frequent strains concerned with infection of humans (Scorza and Lappin, 2005). Feline and canine play a significant role in spread of cryptosporidiosis to humans. Molecular genetic studies revealed that *C. parvum* is not a sole identical species. It consists of six genetically distinct genotype, appear similar in morphology; out of which merely two genotype may be competent to infect immunocompetent humans like AIDS patients (Morgan et al., 1998a; Morgan et al., 1998b). It is necessary that veterinarians need to notify their clients on risk involved. Further contact with pet feline and canine feces needs to be avoided (Lucio-Forster et al., 2010).

TRANSMISSION OF ANCYLOSTOMIASIS

Common hookworms for canines are: *Ancylostoma caninum*, *A. ceylanicum*, *A. braziliense*, and *Uncinaria stenocephala*; and for feline are: *Ancylostoma tubaeforme*, *A. ceylanicum*, *A. braziliense*, and *U. stenocephala*. Persons coming in contact with sand which was contaminated by the faeces of canines and felines hookworms larvae may cause cutaneous larva migrans (CLM). CLM observed in humid areas with persons who crawl underneath buildings (Schantz, 1999). *Ancylostoma spp.* also causes eosinophilic pneumonitis, focal myositis, erythema multiforme, folliculitis and ophthalmological signs in humans (Prociv and Croese, 1996; Landmann and Prociv, 2003). Eggs passed in host's faeces hatch and hookworm larvae released will develop in to infective stage (filariform larva). It gains entry in to final host by skin penetration or ingestion. Infective somatic migration observed in canines where puppies infected by transmammary route, which is uncommon in felines (Bowman, 2010).

EMERGENCE OF ANCYLOSTOMA CEYLANICUM

Ancylostoma ceylanicum is widely distributed in canine and feline in Asian countries which remains an unexplored or less understood zoonotic disease. Current molecular based assays revealed that *A. ceylanicum* is a common hookworm infecting humans which comprised of 6-23% of total hookworm infection (Traub et al., 2008; Jiraanankul et al., 2011). Further, sero-prevalence in canines and feline were around 62% in North-east part of India (Traub et al., 2007b). Natural cases of *A. ceylanicum* have been reported in human populations all over the world where hookworm infections are endemic in canines and felines, but exact clinical reports are lacking. As like any other anthroponotic hookworms, patent *A. ceylanicum* in adult humans lodges in jejunum. Larger numbers of worms causes anaemia, abdominal distension and discomfort, diarrhea and peripher-

al eosinophilia (Anten and Zuidema, 1964; Hsu and Lin, 2012; Croese et al., 1994). Investigations which combine clinical, pathological data along with molecular diagnostic tool may shed the light for future to find its role as human pathogen. Further, it necessitates an incorporated and inter-sectorial "One Health" concept where large numbers of canines share an intimate companionship with humans (Traub, 2013).

TRANSMISSION OF LEISHMANIASIS

Canines in urban areas are the major source of infection for *Leishmania infantum* (Molina et al., 1994; Giunchetti et al., 2006). Zoonotic leishmaniasis is re-emerged and endemic in Europe which was initially considered as insignificant. Leishmaniasis due to *L. infantum* distributed in Mediterranean region, in which canines are the substantiate spreader of infection (Fisa et al., 1999; Sideris et al., 1999). In recent times, infection due to canines is in high magnitude than the expected (Martin-Sanchez et al. 1999; Orndorff et al. 2000). It has been estimated that more than 75% of dogs has seropositivity against *L. infantum*, which harbors as subclinical or in apparent infections. Sharma et al. (2003) reported that the prevalence in canines for *Leishmania tropica* in Rajasthan was about 23 to 40 %. Carrying pet animals to endemic areas for short visit may spread the disease and causes introduction of infection in virgin lands (Robertson, 2000).

TRANSMISSION OF DIPYLIDIASIS

Dipylidium caninum is a common cestode of canines (dogs, cats and wild canids). Humans inadvertently infected under rare circumstances. Fleas act as an intermediate host for *D. caninum*. Cooked rice like proglottids (gravid tapeworm segments) contains packs of eggs are ingested by larvae of fleas. Infective cysticercoids develop simultaneously when larvae mature to adult fleas and transmission of cestode to canine take place due to accidental consumption of flea (Molina et al., 2003). Signs of infection in canines include anal pruritus with mild gastrointestinal signs. Children in contact with pet dogs are more susceptible to infection due to their tendency for pica, and a prominent clinical signs of dipylidiasis in children are presence of gravid segment of cestodes in faeces –proglottids (Mani and Maguire, 2009).

PARASITIC ZONOSSES CONTROL

Control of zoonotic diseases requires education of human population for appropriate cooking method of food before consumption, boiling of drinking water, civilizing hygiene and sanitary measures, but it is huge task to complete (Macpherson, 2005). On the other side, standard and scheduled veterinary care of pet and companion animals against parasitic diseases may prevent zoonotic transmission (Mani and Maguire, 2009). Feeding of pets with un-

cooked meat should be strictly avoided. It has been estimated that almost all dogs (99%) harbors at least any one type of zoonotic parasite in GI tract. Further, about 98% of dogs are out of reach of veterinary care for any health conditions, which remains neither dewormed, nor vaccinated against any diseases (Saminathan et al., 2015). It is very difficult to launch any chemotherapeutic approach to get rid of GI zoonotic parasites in canines in rural circumstances due to involvement of huge cost and subsequent dosing of same dogs may be nightmare. Implementation of stray dog control program and creating public awareness are required. Veterinary officers and physicians should take active role in educating the human community, creating awareness, responsible ownership and implementation of government health control programs. Government funds can be utilized for stray and semi-domesticated dogs control programs and vaccination. Alternate non-chemotherapeutic measures can be utilized for control of zoonotic geohelminth infection by improved education, sanitary measures; personal and environmental hygiene may also decrease and prevent the occurrence of parasitic zoonoses from dogs in rural India (Traub et al., 2007a).

CONCLUSION AND FUTURE PERSPECTIVES

Creating awareness among pet owners and animal handlers have key role in preventing the incidence and occurrence of infections of emerging and re-emerging zoonotic pet parasites. Pivotal knowledge of veterinarians, veterinary scientist, researches and physicians needs to be utilized to minimize the potential parasitic zoonoses by careful monitoring of signs of diseases in humans and animals. Veterinarians in the field are in right place to create awareness and issue sound recommendations, advice, suggestions and guidelines regarding prevention of parasitic infections by timely preventive medications. Widespread and extensive awareness programs are required to reduce the frequency of parasitic zoonotic infections so that pets can be integral family member in house all the way throughout the world. Deterrence and control of emerging and re-emerging parasitic zoonotic infections necessitate a universal pledge not only from scientific community but also from economists, politicians and health professionals to distribute apt financial support in order to carry out intensive control measures. Complete remedial supervision with forecasted plans needs to be created in alliance with scientific community especially with a team of researchers, physician and veterinarian may capitalize on promoting the health of both humans and pets.

CONFLICT OF INTEREST

There is no conflict of interest.

M. Senthil Murugan, and B.R. Singh provided the main concept and designed the study. M. Senthil Murugan and D.K. Sinha managed acquisition of data while M. Senthil Murugan, S. Pavulraj, K. Arunvikram and A. Arun Prince Milton analysed and drafted the manuscript.

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