Canine parasitic zoonoses in India: status and issues

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Summary

Dogs play valuable roles in human society. In addition to serving as pets and companions, dogs have also been important in hunting and, in recent times, as therapy animals. In India, the number of pet dogs is estimated to be around 5 million. The stray dog population in India is estimated to be 19 million and still increasing, owing to ineffective control measures. Stray dogs pose substantial risks to public health due to injury and transmission of zoonoses such as rabies. Both pet and stray dogs may act as reservoirs of zoonotic parasites in India, which has a climate conducive for the environmental survival and transmission of many zoonotic parasites. Presently, visceral larva migrans, cutaneous larva migrans and echinococcosis are the most important parasitic zoonoses in India. Leishmaniasis, dirofilariasis, *Brugia malayi* infection and giardiasis are potentially significant

emerging parasitic zoonoses, and theleziasis, gnathostomiasis and dipylidiasis occur sporadically. Because of their biomedical and public health significance, and the lack of literature and compiled data on parasitic zoonoses of dogs in India, we provide a concise review on this topic along with potential control strategies.

Keywords

Canine – India – Parasitic zoonosis.

Introduction

Humans have shared a close bond with animals for thousands of years. People keep pets for companionship and enjoyment. The dog may have been the first animal to be domesticated and plays a range of cultural, social and economic functions in society (1). Dogs are used in management of many psychological, psychiatric and biomedical conditions in humans (2, 3); for example, assistance dogs help people with certain disabilities to live independently.

Contrary to the psychosocial benefits of well-maintained pet dogs, free-ranging dogs may pose health risks to people as they may harbour a wide range of parasites with zoonotic potential (4). Dogs play a major role in transmission of parasitic zoonoses in India because of many social and environmental factors, and the lack of a robust infrastructure for human and animal disease surveillance and policies for the control of disease and animal populations. In India, wild canids such as foxes (*Vulpes bengalensis*), jackals (*Canis aureus indicus*) and wolves (*Canis lupus pallipes*) also act as reservoirs of zoonotic parasites, and dogs may act as a bridge host between wildlife and people (5, 6). Some parasites such as *Echinococcus granulosus* affect food animals (e.g. sheep, pigs and cattle, which act as intermediate hosts), leading to economic losses through organ condemnation at the slaughterhouse (7). Because of these potential economic and health impacts, we review the prevalence, geographical range, risk factors for human transmission and potential strategies for control of canine parasitic zoonoses in India.

Human and canine populations in India

India, with nearly 1.22 billion people, is the second most populous country in the world and harbours around 17% of the world's population. India's dog population is estimated at 25 million (8), with over 5 million 'pet' dogs. There has also been an increase in the number of Indian families opting to keep companion animals, along with changing lifestyle and social status, and the move away from the concept of nuclear families. In a recent survey, pet dogs were present in 17% of households (n = 8,500) in India, and there was one pet dog for every 36 people (9). India has 19.2 million stray dogs and their population is rising owing to a lack of stringent population control. In addition to free-ranging domestic dogs, Indian wild canids include the fox, wild Indian dog (dhole; *Cuon alpinus*), jackal and wolf (10).

Status of zoonotic parasites in dogs

Important zoonotic parasites that are prevalent in India are *Toxocara canis*, *Ancylostoma* spp., *Echinococcus granulosus*, *Leishmania* spp. and *Toxoplasma gondii*. In addition, *Dirofilaria* spp., *Dipylidium caninum*, *Brugaria malayi*, *Cryptosporidium* spp., *Giardia duodenalis* and *Paragonimus* spp. are emerging parasites.

Toxocara canis infection

Dogs are the definitive host for *T. canis* (dog roundworm). This parasite is more common in dogs less than one year of age. Poor hair coat, failure to gain weight and ill thrift are common clinical signs in dogs. Studies on *T. canis* infection in dogs in India indicate a prevalence of 10–80% (11, 12). In surveys conducted >35 years previously, high prevalence values of 82% in eastern India (11) and 55.8% (13) in western India were observed. In studies conducted from 1990 to 2014, prevalence estimates were 1–45% in western, 9–24% in northern (12), 17–23% in southern (14) and 3–11% in north-eastern India (15). Differences in prevalence may be attributed to geographical, temporal and climatic variations as well as differences in methods of detection (microscopy vs. necropsy), type of dog population studied (strays vs. pets) and sampling bias (adult vs.

puppies, males vs. females). Prevalence was higher and more variable in stray dogs (19–45%) than in pets (9–23%). A high prevalence in stray dogs (14, 16, 17) poses risks to people visiting or living in public places contaminated with their faeces (18, 19).

Ancylostomiasis

Two hookworm species, *Ancylostoma caninum* and *A. ceylanicum*, are found in dogs in India (20, 21, 22, 23). Hookworms cause haemorrhagic diarrhoea in puppies and chronic microcytic hypochromic anaemia in adult dogs. Hookworm prevalence ranges between 19% and 91% in various states (11, 13, 14, 24, 25), with higher prevalence (93–98%) in rural areas (15, 20). Based on a molecular diagnostic approach, both *A. caninum* and *A. ceylanicum* have been identified in dogs from Mumbai, Assam, Sikkim and Tamil Nadu, but only *A. caninum* in dogs from Delhi (20, 21, 22, 23). More than half of stray dogs are shedding *A. caninum*, suggesting that implementation of control measures is urgently needed to address this cause of eosinophilic enteritis (23) and cutaneous larva migrans (CLM) (14, 17).

Dirofilariasis

Dirofilariasis is an emerging zoonosis in India (26). *Dirofilaria immitis* and *D. repens* are the most common species recorded in the country. The distribution of *D. immitis* extends from the Pakistani border in the west, to Delhi and Sikkim in the north, to the Burmese border in the east and to Orissa to the south (26, 27), whereas that of *D. repens* covers central and western India (Mumbai), to Kerala in the south and as far north as Delhi (27). The prevalence of *D. immitis* was found to be 1, 3, 4, 34 and 57% in Sikkim, Kolkata, Delhi, Mizoram and Orissa, respectively (27, 28, 29, 30), whereas that of *D. repens* was 5, 7, 17, 14 and 21% in Delhi, Kerala, Mumbai, Orissa and Karnatka, respectively (26, 29, 31). Note that, without molecular diagnostics, microfilaria of *D. immitis* and *D. repens* in canine blood may not be distinguishable and therefore species-specific prevalence estimates may not be accurate.

Echinococcosis

Although there is a high prevalence (20–48%) of cystic echinococcosis (hydatid cysts, or the metacestode stage of *Echinococcus granulosus sensu stricto*, G1–G3) in intermediate hosts (sheep, goats, cattle) in India there are few surveys on echinococcosis in canine definitive hosts (32, 33, 34, 35). The prevalence in dogs in southern India ranges from 4.35 to 21.2% (34, 35) and that in northern India from 1.41 to 16% (22, 32, 36). In India, transmission is enabled through backyard slaughtering, where stray dogs have access to condemned carcasses and offal with hydatid cysts (32).

Dipylidiasis

Various surveys in India on stray and pet dogs showed dipylidiasis (caused by the cestode *Dipylidium caninum*) to have a prevalence of 12.5–16.10% in northern states (37, 38), 10.25% in central states (39) and 0.56% in north-eastern states. This tapeworm is transmitted through flea intermediate hosts, predominantly *Ctenocephalidis felis orientis* (40.42%) and *C. canis* (10.63%) in dogs in India (40). Lower prevalence (0.97%) was observed in pet dogs (41), compared with 6.0% in stray dogs. Successful management of this parasite requires both cestocides and flea control, particularly in households where children may ingest infected flea intermediate hosts.

Giardiasis

The prevalence of *Giardia duodenalis* by microscopy and polymerase chain reaction (PCR) was 3 and 20%, respectively, in dogs in tea-growing communities of India (15, 42). As there are host specific genotypes/species of *Giardia* in dogs that pose little zoonotic risk, further studies are required on genotyping of *Giardia* isolates in order to better understand the epidemiology and transmission ecology of this disease.

Leishmaniasis

In India, visceral leishmaniasis (VL, caused by *Leishmania donovani*) and cutaneous leishmaniasis (CL, caused by *L. tropica*) are mainly

considered anthroponotic (i.e. humans act as the main reservoir). Recently, out of 31 dogs tested using the rK39 immunochromatographic dipstick test in Himachal Pradesh, 6.5% were seropositive, and it was reported that VL infection is maintained in asymptomatic dogs as a reservoir (43), but further molecular studies are required for confirmation. Elsewhere, Indian desert gerbils (*Meriones hurrianae*) and dogs serve as the reservoirs of CL (44). Himachal Pradesh is an emerging focus for CL (45) and this zoonotic disease is gaining importance in the northern part of the country.

Toxoplasmosis

Dogs, like most mammals, can serve as intermediate hosts for *T. gondii*, which can be transmitted to other intermediate hosts, including people, if consumed in raw or undercooked food. Therefore, dogs could act as sources of human exposure in north-eastern states of India where dog meat is consumed. In addition, dogs coprophagic on cat faeces can mechanically transmit *Toxoplasma* oocysts. However, dogs are generally not considered to be sources of zoonotic transmission of *T. gondii*, but to act as sentinels indicating that local transmission is occurring; therefore, the high seroprevalence of 29.25% in dogs in southern India (46) and 30.9% in northern India (47) may have implications for public health.

Rare canine zoonotic parasites

Most of these parasites have been reported in the last decade and thus may be emerging, or at least newly detected, zoonoses. Although sporadic human cases have been reported in Kerala (48, 49), natural infection with *Thelezia callipaeda* (eyeworm) in dogs has been reported recently for the first time in this province (50). *Brugia malayi*, a causative agent of human filariasis, has been reported in dogs from Kerala. Eighty per cent of dogs were positive for microfilariae, of which 20% had sheathed microfilariae confirmed to be *B. malayi* by PCR (51). Dogs may also act as reservoirs of food-borne helminth zoonoses such as diphyllobothriasis, heterophyiasis, paragonimiasis, opisthorchiasis and gnathostomiasis. A prevalence of diphyllobothriasis of 1–8.57% has been reported in stray dogs that

feed near fish markets (16, 52). Reports of human sparganosis in India suggest the existence of *Spirometra* spp. in its definitive hosts, i.e. wild and domestic canids and felids, but there are few studies in dogs and cats (53, 54, 55). In north-eastern India, where frogs are considered a local delicacy, plerocercoid larvae of *Spirometra* spp. have been reported in frogs (56). Sporadic cases of trematode infestation, including heterophyiasis (11, 57), paragonimiasis (58) and opisthorchiasis (15), have been reported in dogs. Finally, 10% of dogs within Balipara, a tea estate in Assam, were found to have *Gnathostoma spinigerum* eggs in their faeces (15), suggesting that dogs serve as a source of environmental contamination.

Zoonotic parasites in wild canids

Various zoonotic parasites have been reported in wild canids in India (6, 59). Mostly, wild canids are thought to act as subclinical carriers of parasites, although there are few, if any, studies on the health impacts in wildlife. The occurrence of parasites of wild canids in different parts of India is given in Table I.

Insert Table I

Transmission to humans and associated risk factors

Dogs can transmit zoonotic parasites to people in various ways, as shown in Fig. 1.

Insert Fig. 1

Transmission through contaminated soil, water and food

People are exposed to the causative agents of ocular and visceral larva migrans (OLM/VLM, caused by *T. canis*), cutaneous larva migrans (CLM, and eosinophilic enteritis caused by *Ancylostoma* spp.) and cystic echinococcosis (CE, hydatid disease caused by *E. granulosus*) through ingestion of (for VLM/OLM and CE), or contact with (for CLM), soil, water and fresh produce contaminated with dogs' faeces (19, 68, 69). Humans may also acquire VLM through consumption of

encysted larvae of *T. canis* in paratenic hosts, if the parasites are not inactivated by cooking.

Transmission through vectors

Mechanical and biological vectors such as flies, fleas and mosquitoes also aid in transmission of some parasitic zoonoses. Vectors (e.g. *Culex*, *Aedes* and *Anopheles* mosquitoes) and climatic factors that support larval development within the mosquito vectors are present in India (70). Geographical area and flea infestation are the principal risk factors for human dipylidiasis (40).

Other modes of transmission

Though it is considered rare in India, other modes of transmission may include consumption of infected dog meat; for example, toxoplasmosis (caused by *T. gondii*) and trichinellosis (caused by *Trichinella* spp.) may be contracted in this way.

Although the overall significance of direct contact as a route of human exposure to canine parasitic zoonoses is not known, transmission of immediately infective parasite stages (e.g. *Giardia*, *Cryptosporidium* and *Echinococcus*) may occur when petting animals that are contaminated with fresh faecal matter, as may transmission of environmentally transmitted parasites if they adhere to fur, particularly when this is combined with poor animal husbandry and personal hygiene practices.

Risk factors associated with transmission and persistence of canine parasites in India include stray dogs, open defecation and improper faecal disposal, improper meat inspection, and lack of canine deworming and awareness of zoonotic transmission. There are no comprehensive measures in place in India to provide education and knowledge about public health and the factors that contribute to the transmission and public health impact of parasitic zoonoses (71). Lack of proper meat inspection and access of stray dogs to the offal of sheep, goats and pigs, the intermediate hosts of *E. granulosus*, are risk factors for a high occurrence of human CE (36). Defecation in the

open by stray dogs contaminates the environment with eggs of helminths such as *Ancylostoma* spp., *T. canis* and *E. granulosus*, and poses risk to humans living in these areas (72, 73, 74, 75). For example, in Punjab, *Toxocara* spp. eggs were present in 10% of public and private parks examined (18), and *Toxocara* spp. eggs were found in 4.16% of soil samples in different sites contaminated with faeces from pet/stray dog populations in Chandigarh (19). In a recent study in a tribal area of Tamil Nadu, eggs of *Ancylostoma* spp. (*A. ceylanicum* [60%], *A. caninum* [29%] and *A. braziliense* [1%]) were detected in soil (23). Risk factors associated with CLM include low socioeconomic status, improper footwear and sleeping in contaminated environments (76).

Distribution and health implications in humans

Toxocariasis

The populations at greatest risk include children and occupational groups (farm and construction workers, gardeners) with exposure to contaminated soil. *Toxocara* can result in overt clinical syndromes such as VLM and OLM or covert toxocariasis, manifested as subclinical or non-specific symptoms (e.g. abdominal pain) associated with seropositivity for antibodies to *Toxocara*. Depending on the location of infection in the body, VLM leads to abdominal pain, cough, fever, itchy skin, difficulty in breathing, persistent eosinophilia, hepatosplenomegaly (77, 78), seizures or behavioural abnormalities (79, 80). Infection in dogs was reported as early as the 1940s (11), but the first human case of VLM was observed in 1993 in India (77). Since then, sporadic cases of VLM have been reported in various parts of India (78, 79, 81, 82, 83). Recently, a rare case of cerebral larva migrans due to *Toxocara* spp. has also been reported (80). A serological study of human toxocariasis showed a prevalence of 6–23% in northern India (68). The accurate number of cases is not known, suggesting a need for enhanced surveillance and reporting systems.

Redness, watering of the eyes, anterior uveitis, secondary glaucoma, periocular swelling, photophobia and loss of vision are the clinical

manifestations of OLM (84, 85). Ocular toxocariasis has been reported in northern India (86, 87). In addition to *Toxocara*, the nematode *Gnathostoma* can also cause OLM in people, but routes of transmission of these two parasites are different. As definitive hosts of *Gnathostoma*, dogs amplify transmission, but are not a direct source of zoonotic transmission (humans are infected through ingestion of fish or frog intermediate hosts). Only isolated cases of ocular gnathostomiasis have been reported, most of them from the coastal areas of India (84, 87, 88, 89, 90). Access of stray dogs to recreational areas such as beaches should be restricted to avoid contamination and prevent public health risks.

Cutaneous larva migrans and eosinophilic enteritis

The clinical signs of CLM vary from mild dermatitis to creeping eruption, where larvae moving below the skin lead to serpiginous, erythematous and pruritic lesions (73, 74, 75). Although the occurrence of ancylostomiasis is high in dogs, human CLM has been reported only sporadically in India (72, 73, 74, 75). There appears to be no report of *A. caninum*-induced eosinophilic enteritis, but because the condition has a vague clinical presentation it is likely to be under-diagnosed and under-reported. A study reported in 1972 indicated 9% prevalence (16/183) of *A. ceylanicum* in people from the outskirts of Calcutta (91). Since morphological differentiation of *Ancylostoma* spp. eggs in faeces is impossible, it is probable that the latest human studies assumed the species to be *A. duodenale* (19, 20). A recent study using semi-nested PCR–restriction fragment length polymorphism (RFLP) identified *A. ceylanicum* in 2 out of 41 children from a tribal community in Tamil Nadu (92).

Dirofilariasis

Humans are exposed to microfilaria through the bite of an infected mosquito. *Dirofilaria repens* mostly causes ocular infections (93, 94) while pulmonary dirofilariasis is mostly caused by *D. immitis* (95). Whereas the parasite is considered to be endemic in southern India (26), sporadic reports are documented from the northern (96), eastern (97) and western regions (95) of the country.

Cystic echinococcosis

Cystic echinococcosis (CE) is endemic in India as the conditions conducive to the establishment, propagation and dissemination of the cestode in both humans and livestock are present. The annual incidence of CE varies from 1 to 200 per 100,000 persons (98). High prevalence is reported from Tamil Nadu, Andhra Pradesh, Kashmir and Central India (99, 100). The prevalence in urban centres has been consistently decreasing over the past few decades, possibly due to economic development and improved government legislation of abattoirs (101). The predominant genotypes in humans in India are the G1 (sheep strain) and G3 (buffalo strain) genotypes of *E. granulosus* (102).

Dipylidiasis

Although *D. caninum* has been reported all over the world, zoonotic transmission is rare and is largely thought to occur in children who accidently ingest flea intermediate hosts. It is rare in humans in India (103, 104).

Giardiasis

The prevalence in people ranges from 11% in the north (105) to 53.8% in the south (106) of India. In patients with human immunodeficiency virus (HIV) infection, the prevalence of *G. duodenalis* was 8–27% (107, 108). Molecular epidemiological studies are required to determine whether *Giardia* present in humans are acquired from animals, other people or shared contaminated environments.

Leishmaniosis

Visceral leishmaniasis (VL) is prevalent in the hot and humid eastern states, while the drier western parts (such as the Thar Desert) are considered to be endemic for CL (109, 110). A large outbreak of CL occurred in Bikaner in 1973 (111). Further research into the epidemiology, geographical distribution and inter-species interactions of the *Leishmania* parasite is required.

Other rare zoonoses

Only seven cases of theleziasis have been reported (48, 49, 112, 113, 114). Filariasis is endemic in 17 states and 6 Union Territories, with about 553 million people at risk of infection in India, and the government has accorded high priority for elimination of this infection through a mass chemotherapy programme (115). All reported human cases of diphyllobothriasis are from south India, and can be attributed to dietary preferences for fish in that part of the country (116). Although few cases of sparganosis have been reported from India, it should be considered a differential diagnosis because of the serious consequences if appropriate treatment is not initiated promptly (117, 118).

Control measures

Robust surveillance and monitoring programmes for important parasitic zoonoses in pet and stray dogs, as well as in humans, should be launched on a national level. Proper diagnostic techniques are key in such surveillance and monitoring programmes; for example, the inaccuracy of morphological diagnosis of ancylostomiasis based on egg morphology in faecal samples from dogs in India demonstrates the need to add molecular diagnostic tools to existing traditional parasitological techniques (21).

The problem of parasitic zoonoses is highly complex and integrated. Therefore, an integrated multidisciplinary approach is necessary, such as 'One Health', which includes, but is not limited to, medical, veterinary, environmental, ecological, sociological and economic experts, as well as policy makers and engaged communities. Veterinary public health control can decrease prevalence in animals and zoonotic transmission of parasites. Often these control measures, such as restricting the access of stray dogs to condemned carcasses/offal, and prompting animal deworming and meat inspection, are well known, but implementation remains elusive because of a lack of resources, community involvement, regulatory enforcement and/or policy promotion. Within traditional public health, health promotion, by means of school-based programmes including

regular physical examinations, human deworming and improving standards of hygiene, plays a cardinal role in prevention and control of disease in people. Such programmes do not exist for companion animal populations. Prevention also involves avoidance of raw or inadequately cooked freshwater fish, frogs, snails, pork and other foods of animal origin, as well as contaminated produce. Proper sewage disposal and treatment of drinking water may also prevent parasite transmission in the community. Educational programmes targeting zoonoses with canine reservoirs are required to raise awareness in the general public, especially in endemic areas and vulnerable populations (such as those living under conditions of low socioeconomic status).

Future challenges

There are some canine zoonotic parasites which are not reported in dogs in India but human cases have been found, highlighting the inadequacy of animal surveillance and reporting. In such cases, people serve as sentinels of parasitic zoonoses instead of, ideally, detecting them in animal reservoirs. For example, no cases of *Trichinella* spp. have been found in dogs in India, but it is likely that they are infected because multiple outbreaks of human trichinellosis have been reported (119). The most important source of human trichinellosis is consumption of infected wild boar or pork, but consumption of dog meat can also lead to human infection (120, 121). In India, dog meat is only eaten by certain communities in the north-eastern states of Mizoram, Nagaland and Manipur, where it is considered to be a delicacy. Improper meat inspection and consumption of dog meat are modifiable risk factors that could be addressed to decrease overall transmission of this parasite.

The occurrence of *Gnathostoma* spp. infection has been reported in wildlife (122, 123), including most recently in a free-ranging tigress in Pench Tiger Reserve, Madhya Pradesh (124). Canine species act as definitive hosts, and further study is needed to determine their role in amplifying and disseminating this parasite in the environment. Given that 10% of dogs within Balipara, a tea estate in Assam, were found to

have *Gnathostoma spinigerum* eggs in their faeces (15), this parasite requires further study.

A weak association has been observed between contact with dogs and the occurrence of cryptosporidiosis (generally manifested as diarrhoea), especially in immunocompromised persons (125, 126, 127). India has a population affected with HIV/AIDS (acquired immune deficiency syndrome) of approximately 1.4–1.6 million people (128). Approximately 45,000 deaths due to diarrhoea occur annually in children aged 5–14 years in India (129). In the current scenario, there is a need for molecular epidemiological studies to determine the role and source of protozoa in immunocompromised and paediatric patients in India.

Conclusion

In order to tackle canine parasitic zoonoses in India, the importance of parasitic infections must be recognised by both physicians and veterinarians. Control of infection in dogs is necessary for prevention in humans. As stray dogs represent a large reservoir of zoonotic canine parasites (along with other zoonoses such as rabies), controlling the stray dog population is important, through methods such as surgical, chemical or hormonal sterilisation and/or municipal bylaws. These are greatly preferable to reactive culling, which provides only a short-term solution to a long-term problem. From a public health viewpoint, the ubiquity of zoonotic parasites in dogs in India warrants an appropriate surveillance programme in combination with population control for stray dogs, deworming of pet dogs, control of vectors, proper meat inspection of food animals and increased general public awareness of the risk factors and control measures for zoonotic parasites.

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Table I
Occurrence of zoonotic parasites in wild canids in India

Parasite	Wild canid hosts	Place	Reference
Toxocara sp.	Wild dog	Satpuda	60
	Jackal	Darjeeling	6
Ancylostoma sp.	Jackal	Kerala	5
	Jackal	Tamil Nadu	61
	Golden jackal, Indian fox, wolf	Gujarat	62
	Jackal	Maharashtra	63
	Jackal	Tamil Nadu	64
Dirofilaria sp.	Indian fox, wolf, jackal & wild dog	Orissa	65
Echinococcus granulosus	Indian wolf	Orissa	66
Dipylidium sp.	Golden jackal, Indian fox, wolf	Gujarat	62
	Wild dog	Satpuda	60
Diphyllobothrium sp.	Wild dog	Satpuda	60
	Jackal	Nagpur	59
	Fox	Maharashtra	63
Paragonimus sp.	Wild dog	Satpuda	60
	Wolf	Nagpur	67
Spirometra sp.	Wild dog	Satpuda	60

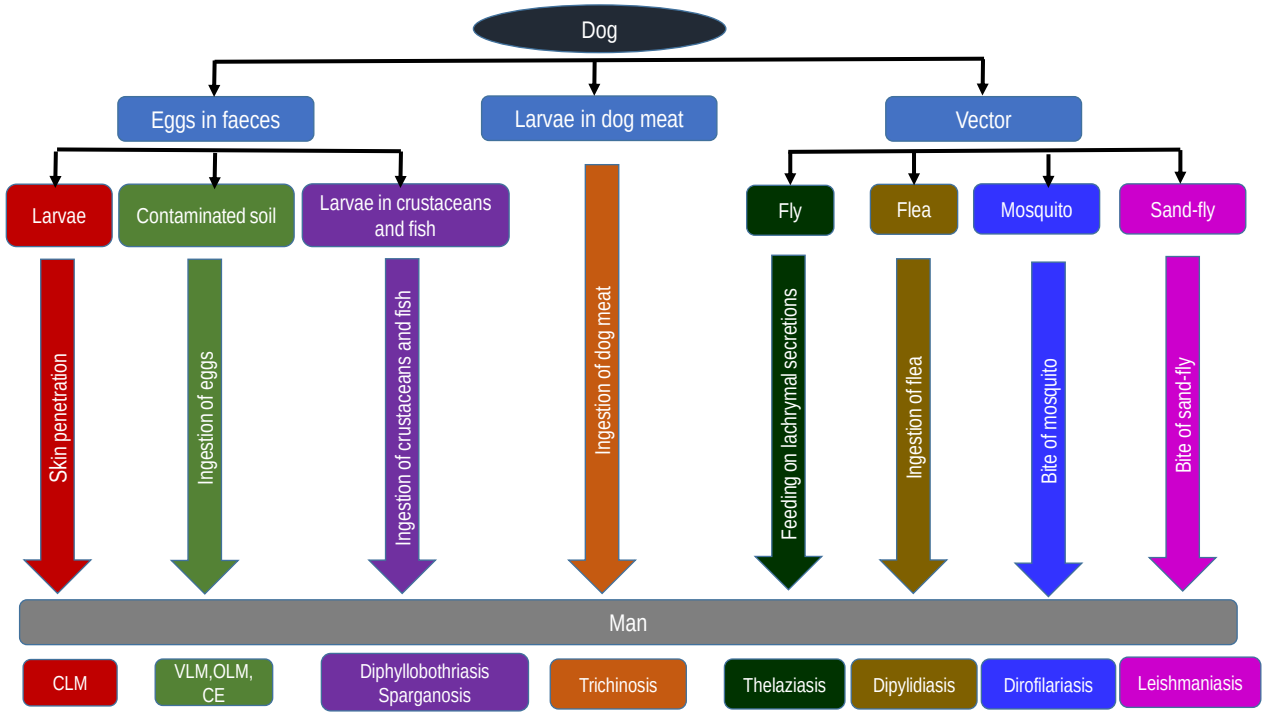

Fig. 1

Transmission of canine zoonotic parasites

CE: cystic echinococcosis

CLM: cutaneous larva migrans

OLM: ocular larva migrans

VLM: visceral larva migrans