

Veterinary and Public Health Significance of Canine Hookworm (*Ancylostoma caninum*) in Nepal: An Integrated One Health Approach

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ABSTRACT

Ancylostoma caninum is a highly pathogenic parasite of canines, causing Canine hookworm disease, particularly in tropical and subtropical regions such as Nepal. This hookworm infection in canines leads to major pathological manifestations, including anemia, hemorrhagic enteritis, diarrhea, and growth retardation. Young puppies and immunocompromised humans are at high risk of infection. Human beings are incidental hosts, most often presenting with cutaneous larva migrans (CLM) and, in rare cases, eosinophilic enteritis. Domestic and free-roaming dog populations perpetuate the spread of infections by contaminating the environment with infective larvae shed in canine feces, thereby increasing community health risks. In Nepal, parasitic infections are prevalent; deworming is inadequately practiced, and humans remain in close, unmonitored contact with free-roaming dogs.

This review summarizes biology, life cycle, transmission, clinical effects, epidemiology, diagnostics, anthelmintic resistance, and control measures of *A. caninum*, as well as its zoonotic potential and human health significance. Limitations of traditional diagnostic methods highlight the importance of molecular methods for species-specific identification and resistance monitoring. An integrated One Health approach, including routine deworming of dogs, improved environmental sanitation, community awareness, and strong intersectoral collaboration, plays a major role in reducing infection rates and limiting zoonotic transmission. This is an evidence-based overview of sustainable interventions that offers structural support to One Health initiatives aiming to mitigate the burden and transmission of *Ancylostoma caninum* in Nepal.

Keywords: *Ancylostoma caninum*, Anthelmintic Resistance, Canine Parasite, Cutaneous Larval Migrants, One Health Approach, Zoonotic Helminths

ABBREVIATIONS

AR: Anthelmintic Resistance

CLM: Cutaneous Larva Migrants

FECRT: Fecal Egg Count Reduction Test

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ITS: Internal Transcribed Spacer

L1/L2/L3: First/Second/Third-Stage Larvae

PCR: Polymerase Chain Reaction

SNP: Single-Nucleotide Polymorphism

INTRODUCTION

Hookworm infection is the most common gastrointestinal parasitic infection in dogs worldwide and is a serious concern for animal and human health, particularly in tropical and subtropical areas [1]. Canine hookworm infections represent a primary cause of morbidity in dogs. They lead to chronic intestinal blood loss, microcytic anemia, impaired growth, and reduced physiological performance, which increases host vulnerability to secondary infections [2].

Ancylostoma caninum, the most prevalent pathogenic species, causes severe illness in canines in Asia, Africa, and Latin America [3,4]. The remarkable biological success of *A. caninum* is attributed to its high hematophagic activity, prolific egg production, a simple direct life cycle, and the ability to infect the host by several different routes, such as skin penetration, oral ingestion, transmammary infection of nursing pups, and through paratenic hosts, including rodents [5]. These biological properties of canine hookworms largely contributed to the persistence of *A. caninum* in the canine population, leading to failure of partial anthelmintic therapy and environmental control measures [6]. Environmental factors such as high temperatures, elevated humidity, and moist soil strongly favor growth, survival, and infectivity of hookworm larvae, leading to protracted contamination and increased transmission risk in canine habitats [7].

Nepal is an ecologically diverse South Asian Country that offers favorable conditions for the reproduction and survival of the canine hookworm and other canine gastrointestinal parasites [8]. Along with the extended monsoon season, roaming dogs, lack of veterinary care, irregular deworming, and lack of fecal disposal led to persistence of canine helminth infection and continuous environmental pollution among Nepalese communities [9,10]. Despite these risk factors, the epidemiology of hookworm infection in dogs in Nepal has not been comprehensively investigated, and species-specific data remain lacking.

Along with its veterinary importance, *A. caninum* has been recognized as an emerging zoonotic pathogen, and cases of eosinophilic enteritis and other clinical manifestations have been increasingly reported in humans [11]. Cutaneous Larval Migrants in humans is the most common disease

acquired through percutaneous infection of infective larvae in contaminated soil [12]. Cases of eosinophilic enteritis attributable to the infection of *A. caninum* are uncommon in humans, but are convincing evidence of its capacity to create intestinal disease and support its importance as an emerging zoonotic parasite [13]. There is sustained contact among human beings, domestic and stray dogs, and the environment in Nepal. A comprehensive understanding of the biology, epidemiology, zoonotic potential, and control of *A. caninum* is essential to address this research gap and provide an evidence-based control strategy within a One Health framework.

METHODOLOGY

This review was conducted to synthesize available data on *Ancylostoma caninum* in dogs and its public health concern in Nepal, with a focus on veterinary, zoonotic, and One Health perspectives. A search of electronic databases (PubMed, Scopus, Web of Science, and Google Scholar) and relevant local journals and grey literature from governmental and non-governmental veterinary alliances was conducted. Search excerpts included terms such as *Ancylostoma caninum*, canine hookworm, zoonotic hookworm, cutaneous larva migrans, Nepal, anthelmintic resistance, and One Health. Articles and reports published in English during 1950-2025, which contained information about the biology, epidemiology, clinical effects, diagnostics, and the potential of *A. caninum* to be a zoonosis, or the methods of controlling this nematode parasite, were considered, but those with missing data were excluded, as well as articles that did not refer to this pathogen. Systematic data extraction was carried out, with the results being organized into thematic categories, that is, taxonomy and morphology, life cycle and transmission, pathogenesis and clinical manifestations in canines and humans, epidemiology in Nepal, diagnostics, anthelmintic resistance, and integrated control measures. These trends, knowledge gaps, and risk factors (especially molecular diagnostic evidence and emerging resistance patterns) were identified through a qualitative synthesis. This strategy outlined the overall approach to implementing sustainable interventions, planning public health and One Health strategies, and reducing the impact of *A. caninum* infection on canine and human populations.

Taxonomy and Morphology

Taxonomically, *Ancylostoma caninum* belongs to the phylum Nematoda, class Chromadorea, order Strongylida, and family Ancylostomatidae [4]. The worms are stout and cylindrical,

with a length of 10-20 mm and females larger than males [14]. The worms are rigid and reddish in color, with an anterior end that bends dorsally to form a characteristic hook. The buccal capsule bears three pairs of teeth on the ventral margin, which is the main morphological feature of this worm [15]. Sexual dimorphism was also present, as females were bigger than males; males were about 10-12 mm long, and females were about 14-16 mm long. The male had a well-developed copulatory bursa at the end of the posterior. In females, the vulva is located near the junction of the second and final thirds of the body [4,13,16]. One of the primary pathogenic features of *A. caninum* is its heavily sclerotized buccal capsule armed with three pairs of sharp ventral teeth, which allow it to anchor securely to the mucosa and feed on blood [17]. Worms of female *A. caninum* are extremely fecund (as many as 30,000 eggs per day), which also plays a significant role in the contamination of the environment and in the transmission of the worm [4,16]. Even under routine light microscopy, the eggs of *Ancylostoma caninum* cannot be identified to the species level without the use of molecular diagnostic methods due to morphological similarity to other *Ancylostoma* species, such as *A. ceylanicum* [18,19]. This shortcoming requires species identification using molecular diagnostic methods, especially where zoonotic hookworm species overlap.

Life Cycle and Transmission

Life Cycle

Ancylostoma caninum has a direct, environmentally mediated life cycle that is highly adaptable, making it highly prevalent among canine populations [20]. Adult worms residing in the small intestine of infected dogs produce a large number of eggs, which are shed in the feces [21]. Under favorable conditions, specifically warm temperatures, adequate moisture, and sufficient oxygenation, embryos develop rapidly and hatch within 24 – 48 hours to release first-stage (L1) rhabditiform larvae [22].

The L1 larvae actively feed on organic materials and microbes in the soil, and the larvae continuously develop in a series of two molts (L1 to L2 and L2 to L3) in a span of about 5-10 days, depending on environmental factors [23,24]. The resultant third-stage (L3) filariform larvae are the infective stage and are distinguished by a protective cuticle, which improves survival but does not permit further feeding [25]. The larvae are active and localized to the top of the soil, where they are sensitive to thermal and moisture gradients that enable them to come into contact with their hosts [26].

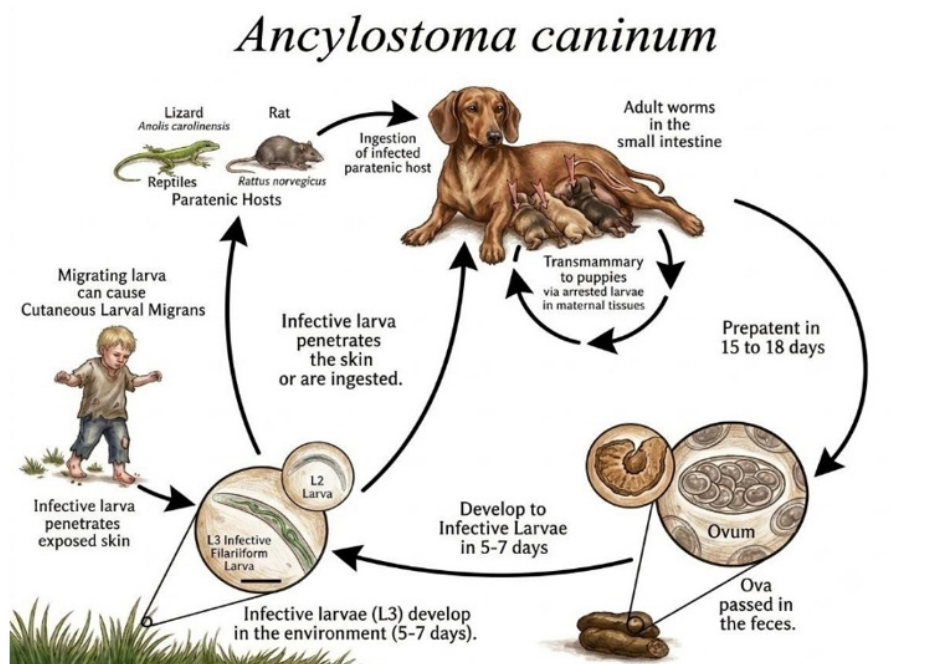


Figure 1: Life Cycle of *Ancylostoma caninum*

The environment helps perpetuate transmission by allowing infective larvae to survive. Under favorable circumstances, moderate temperatures (around 20-30 °C), high humidity, and shaded living environments, L3 larvae can live several weeks or months, causing a significant level of contamination to the environment and host exposure [27]. The infective L3 larvae may be introduced through cutaneous penetration, oral ingestion, or infestation of paratenic hosts, then invade tissues and ultimately develop into adult worms in the small intestine when they encounter a suitable host [28]. Additionally, a certain percentage of larvae can become somatically arrested in host tissue, contributing to chronic infection and vertical infection in the next reproductive cycle [29]. *A. caninum* has efficient transmission and persistence due to the combination of rapid environmental development, larval survival, and multifaceted routes of infection in both domestic and free-roaming dog groups.

Transmission

Ancylostoma caninum is transmitted through well-known and supplementary routes that together maintain the parasite within the canine population inhabiting a wide range of ecological conditions. Under natural conditions, percutaneous infection by infective third-stage (L3) larvae occurs through intact skin, most commonly across interdigital spaces, footpads, and the ventral abdomen [30]. Dermal exposure experiments have established that the larval establishment rate is greater than oral infection, therefore proving the epidemiological importance of skin penetration, e.g., through dogs that are highly exposed to the environment [31].

Oral ingestion of infective L3 larvae via contaminated soil, water, plants, or fomites represents another epidemiologically significant pathway [32]. They can survive for prolonged periods under warm and humid conditions and can be infected in canines during normal activities like grooming, scavenging, and feeding [33]. Free roaming dogs are highly vulnerable to infection by this route in the polluted and contaminated environment.

The transmammary route is the most important source of vertical transmission of *A. caninum*, especially in neonatal and juvenile dogs [34]. Infected bitches can have their larvae put into somatic arrest and then hormone-activated in late pregnancy or lactation, which enables them to migrate to the mammary glands, where they are passed on to suckling puppies in colostrum and milk [35]. This process leads to early, high-intensity infections in puppies and plays a significantly to age-related prevalence pattern in endemic regions [36].

Besides, rodents and other small mammals, which are not infected directly, can harbor encysted larvae and act as auxiliary reservoirs. Dogs are infected by predation or consumption of these hosts, hence increasing the spread of the parasites beyond direct contact with the contaminated environment, and increasing the survival of the parasites under changing ecological conditions [37,38].

After infection by any transmission route, infective L3 larvae experience systemic somatic migration. Larvae penetrate the skin, and then the circulatory system reaches the lungs, where they crack through the alveoli, climb the trachea, are swallowed, and then develop into adult worms in the small intestine [39,40]. One of the characteristic features is that it can undergo dormancy inside the host tissue and reactivate during pregnancy [41]. The environmental, vertical, and paratenic pathways of transmission coincide, which poses significant difficulties for an intervention program and is one of the primary factors contributing to the high level of infection rates reported consistently in puppies and free-ranging dogs that experience intensive exposure to sources of infection early in life [42,43].

Pathogenesis and Clinical Manifestations

In Canines

Infection with *A. caninum* in dogs is complicated by persistent blood feeding by adult worms, mucosal adherence, and larval migration. Canines become infected through percutaneous exposure, which occurs in the footpad interdigital spaces and the ventral abdominal region [44].

The invasion through basement membranes and the dermal and vascular tissue is facilitated by its mechanical motility and the release of proteolytic enzymes such as cysteine protease and metalloprotease [45,46]. This migration will have a clinical presentation of localized inflammatory responses, including eosinophilic infiltration, edema, and pro-inflammatory cytokine release, which will have a clinical presentation of pruritus and erythema at the site of penetration [47,48]. When the adult worms arrive at the small intestine, they adhere to the mucosa with the help of buccal teeth and secrete a defined set of anticoagulants, proteases, and hyaluronidases into the intestine, which enable them to penetrate the tissue by preventing clot formation and allowing them to efficiently extract nutrients from blood [49,50]. Prolonged hematophagy leads to iron-deficiency anemia, hypoproteinemia, and a decrease in packed cell volume, whereas massive mucosal damage leads to hemorrhagic enteritis, diarrhea, dehydration, and abdominal discomfort [51,52].

Transmammary transmission, an immature immune system, and low iron levels make the puppies very vulnerable. Neonatal puppies are particularly vulnerable, and rapid parasite mutation within the intestine causes acute, severe anemia, ascites, and peracute mortality if left untreated [53,54]. Sublethal infections, though, can result in impaired growth and immunity, which makes animals susceptible to secondary infections [55,56].

At the molecular level, cysteine-containing proteins, metalloproteins, and anticoagulant proteins play key roles in host tissue invasion, immune evasion, and chronic infections caused by *A. caninum*. These proteins are also promising as therapeutic intervention targets and vaccines [57,58].

Public Health Significance

In humans, *Ancylostoma caninum* infection typically manifests as cutaneous larva migrans (CLM), a zoonotic dermatitis inflicted by the percutaneous penetration and subsequent epidermal migration of infective larvae [59]. The characteristic clinical appearance of CLM is the emergence of serpiginous tracks of intensely pruritic, erythematous lesions that enlarge as the larvae move in the superficial skin layers [60]. These lesions develop in body sites that are frequently exposed to contaminated soil, such as the feet or limbs. Though the larvae cannot complete their life cycle in human beings, excoriation and secondary bacterial

infections are typical sequelae of prolonged pruritus, and the symptoms may not fade away in several weeks without treatment [61,62].

In rare circumstances, infective larvae may deeply penetrate human subdermal tissues and migrate to visceral organs, a condition mimicking visceral larva migrans [63,64]. An eosinophilic enteritis is one of the described manifestations and is associated with pain in the abdomen, significant peripheral eosinophilia, and inflammatory changes in the intestinal mucosa [65]. These abnormal clinical findings indicate disrupted larval migration, and clinical cases have been reported to involve host inflammatory responses.

Epidemiology in Nepal

Several studies in Nepal show that the prevalence of *A. caninum* in stray and owned dogs is consistently high, particularly in urban and peri-urban areas. The reported prevalence ranges from approximately 49% to over 95%, with many more infections among the free-roaming dogs and puppies [8,66].

A. caninum is often viewed as highly prevalent and poses an important zoonotic threat, particularly in highly populated regions where humans and dogs have frequent contact with each other. Such observations underscore the urgent need for structured surveillance and control programs.

Table 1: Epidemiological observations compiled across major regions of Nepal

Category	Location/Year	Population	Prevalence/cases	Reference
Canine Hookworm	Kathmandu (2012/13)	210 dogs	52%	[10]
	Rupandehi (2017)	400 dogs	46.81%	[67]
	Kathmandu Valley (2021)	120 dogs	39.39% (stray), 6.66% (pet)	[68]
	Kathmandu (2022)	88 dogs	73.86%	[69]
	Suryabinayak, Bhaktapur (2023)	400 dogs	49.16%	[8]
	Western Chitwan, Bharatpur (2025)	103 dogs	74.57%	[70]
Human CLM	Kathmandu (2022)	45-year-old male	1 reported CLM	[71]
	Myagdi (2023/2024)	4-year-old child	1 reported CLM	[61]
	Kathmandu (2024)	3 patients	3 reported CLM	[72]

Epidemiological observations compiled across major regions like the Kathmandu Valley clearly illustrate a stark divide in risk profiles; owned pet dogs exhibit a significantly lower prevalence (6.66%) compared to unmanaged free-roaming populations, which exceed 73% in high-density urban areas. The climatic conditions and larger unmanaged dog population contributed to the higher prevalence in Western Chitwan. Improper, irregular deworming practices also play an important role in the persistence of that problem in that area. The emergence of Cutaneous Larval Migrans (CLM) cases highlights the zoonotic risk and requires improved parasite control and public health awareness.

Molecular Diagnostics

The most commonly used diagnostic method is microscopic fecal examination; however, it lacks the specificity required to differentiate *A. caninum* from morphologically similar species [4,73]. Besides, in mixed infections, the prepatent period may affect the microscopic sensitivity of the infection and lead to underestimation of infection prevalence and zoonotic capability [74].

These limitations are overcome by molecular diagnostic methods, mainly PCR, which enable specific diagnosis of *A. caninum*. The internal transcribed spacer or ITS-1 and ITS-2 of ribosomal DNA, mitochondrial cytochrome C oxidase subunit 1 (cox1), and the β -tubulin gene are very sensitive to PCR and allow phylogeny and population genetic studies [75]. Significantly, β -tubulin gene markers are being increasingly employed in the study of genetic diversity and benzimidazole resistance in *A. caninum* to provide important information on the effectiveness of treatment and the evolution of the parasite [76,77]. Molecular analyses have also shown that *A. caninum* is often co-infected with zoonotic species, including *A. ceylanicum*, which is often not detected by a microscopy-based approach [78,79]. In Nepal, an ecologically diverse place where close, sustained interaction between humans and dogs, either as pets or as a large number of free-roaming stray dogs, along with poor sanitation, requires incorporation of a molecular diagnostic approach, which is crucial in disease surveillance, epidemiology, and zoonotic risk assessment, and One Health control strategies.

Anthelmintic Resistance

The problem of anthelmintic resistance (AR) in *Ancylostoma caninum* is an emerging concern in the global community, especially in dog populations that are exposed to regular and, often, indiscriminate deworming. Resistance has

increased worldwide to major classes of anthelmintics, such as benzimidazoles, macrocyclic lactones, and pyrantel, and in several countries, there have been reports of multidrug-resistant strains of *A. caninum* [80-82]. The primary drivers of resistance include sub-therapeutic dosing, lack of drug rotation, and an absence of routine efficacy monitoring in shelters, breeding facilities, and free-roaming dog populations [83].

The molecular basis of benzimidazole resistance in *A. caninum* is primarily attributed to single-nucleotide polymorphisms (SNPs) at codons 167 (F167Y), 198 (E198A), and 200 (F200Y) of the beta-tubulin gene, conferring resistance to benzimidazoles, responsible for treatment failure, perpetuation of egg shedding, and contamination of the environment [84,85]. Even though there is currently a lack of data on AR in *A. caninum* in Nepal, the presence of widely used anthelmintics, the lack of veterinary control, and the high number of free-roaming dogs all indicate a strong probability of AR developing. This highlights the necessity to conduct urgent surveillance with fecal egg count reduction tests (FECRT) and molecular identification. Public health initiatives should focus on community-level awareness campaigns that advocate for hygiene education, consistent use of protective footwear, and responsible animal handling [89]. Enhanced surveillance using molecular diagnostic methods and active monitoring of anthelmintic resistance will provide high-resolution data on species distribution and the emergence of new patterns of drug resistance, ultimately allowing timely modification of control measures. Intersectoral integration among environmental health specialists, human health practitioners, and veterinarians is essential to reduce transmission and maintain sustainable control measures within a One Health framework [86,90].

One Health Approach

The most effective management of *Ancylostoma caninum* and other zoonotic hookworms requires a One Health approach that aligns the veterinary, environmental, and public health sectors. On the veterinary side, regular deworming of dogs, especially early and frequent treatment of puppies, and control of the population of free-roaming and stray dogs by sterilization and responsible ownership programs can contribute significantly to reducing the reservoir of infection and environmental contamination of infective larvae [86,87]. These environmental sanitation practices are necessary to break the transmission cycles and reduce human contact with the larval forms of infection in endemic areas, such

as the adequate collection and disposal of canine feces, as well as soil contamination of public and recreational spaces [86,88]. Public health initiatives should focus on community-level awareness campaigns that advocate for hygiene education, consistent use of protective footwear, and responsible animal handling [89]. Enhanced surveillance using molecular diagnostic methods and active monitoring of anthelmintic resistance will provide high-resolution data on species distribution and the emergence of new patterns of drug resistance, ultimately allowing timely modification of control measures. Intersectoral integration among environmental health specialists, human health practitioners, and veterinarians is essential to reduce transmission and maintain sustainable control measures within a One Health framework [86,90,91].

CONCLUSION

Ancylostoma caninum remains a highly prevalent and clinically important hookworm of dogs that poses a significant problem for veterinary and public health, especially in tropical and subtropical areas like Nepal. Despite regular control measures, environmental resistance, vertical transmission, and various modes of transmission, it continues to circulate in the canine population. The consistently high prevalence reported in both free-roaming and owned dogs in Nepal indicates high environmental contamination and is important to the parasite's epidemiology. In addition, cutaneous larval migrans and infrequent cases of eosinophilic enteritis are increasing the zoonotic potential of *A. caninum* in humans.

A. caninum requires a One Health approach to be effectively controlled, including routine deworming of dogs, responsible dog population management, environmental sanitation, community education, and enhanced surveillance. Weaknesses of traditional microscopy and the growing threat of anthelmintic resistance on a global scale underscore the importance of molecular diagnostics and resistance surveillance to inform evidence-based interventions. In Nepal, it is necessary to develop species-specific epidemiological and molecular data through of resistance-related mutations as a part of One Health.

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Author Contributions

P.T.M. conceptualized the review, performed the primary literature search, and drafted the manuscript. S.P.K. and A.K. contributed to data synthesis, literature collection, and drafting sections on epidemiology and clinical manifestations. D.B. and S.S. assisted in compiling veterinary diagnostic and therapeutic data and preparing the tables. S.R. supervised the study, reviewed the parasitological frameworks, and critically revised the manuscript for intellectual content. All authors read, reviewed, and approved the final manuscript.

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Availability of data and materials

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Ethics and Consent to Participate declarations

Not applicable

Consent for publication

Not applicable

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