Review

Discuss the Transmission Dynamics of *Fasciola hepatica*, Including the Role of Intermediate Hosts, Water Contamination, and Human Behavior

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Abstract | *Fasciola hepatica*, a liver fluke parasite, is a significant zoonotic pathogen with a sophisticated lifecycle including freshwater snails as intermediate hosts and vertebrates like humans and livestock as definitive hosts. The infection is mostly due to the ingestion of infected water or aquatic plants. Climate conditions like rainfall, humidity, and temperature have a major impact on parasite transmission by facilitating snail growth. Human activities such as agriculture and irrigation also aid in water pollution and parasite dispersal. *F. hepatica's* lifecycle is initiated by eggs excreted in feces that develop in freshwater. Motile miracidia infect snails, going through stages of development to become cercariae, which encyst on aquatic vegetation as metacercariae. The parasite, upon being ingested by a definitive host, migrates into the liver and hemorrhages and damages it before reaching maturity in the bile ducts. Its wide global distribution is indicated by regions endemic in South America, Africa, Southeast Asia, and Europe. Climate change intensifies fascioliasis through changes in temperature and rainfall patterns, promoting snail survival and parasite development. Control interventions are intermediate host management, anthelmintic treatments such as triclabendazole, and public education. Enhanced irrigation practices, vaccine development, and predictive models of outbreaks provide approaches to reduce the public health and economic impact. An understanding of the transmission dynamics of *F. hepatica* is key to formulating sustainable prevention and control measures.

Keywords | Transmission, Human activities, Intermediate hosts, Water contamination, Climate change, *F. hepatica*

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INTRODUCTION

F. hepatica transmission is a multifaceted process incorporating the parasite, its intermediate hosts, and several environmental factors. This parasitic flatworm has specific hosts, including freshwater snails and vegetation, which it needs to complete its life cycle and become infective (Mas-Coma *et al*., 2005). Unfortunately, infected hosts can be carried by contaminated water sources, thereby spreading the parasite. Human activity, such as agriculture, also has the potential to contaminate water sources, thus heightening the risk of infection. When individuals eat raw or undercooked plants cultivated using dirty water, they become infected (Mas-Coma *et al*., 2005).

F. hepatica transmission is also affected by the environment, such as weather conditions, humidity, and precipitation. For example, high temperatures and high rainfall provide perfect conditions for snails to thrive, thereby leading to a high risk of infection in humans and domestic animals (Esteban *et al*., 2019). To overcome this, there is a need to design effective control measures, including enhancing water management, encouraging proper hygiene, and educating communities on the disease. Understanding the transmission dynamics of *F. hepatica* helps us mitigate the spread of this important public health issue (Esteban *et al*., 2019).

Definition

These liver flukes are one of the largest parasitic organisms to infect humans, being 25-30 mm in length and 10-15 mm in breadth, and are digenean parasites (Hurtrez-Boussès *et al*., 2001).

Life cycle and intermediate host

The definitive host of *F. hepatica* is usually a vertebrate, including most often mammals like humans, cattle, sheep, and rabbits, but infection has also been reported in birds (Hurtrez-Boussès *et al*., 2001). The intermediate host is a hermaphroditic snail of the family Lymnaeidae, which lives in aquatic environments such as ponds. Definitive host infection is usually through the consumption of aquatic plants like watercress and mint or through drinking contaminated spring water (Rondelaud *et al*., 2000). When the encysted infective stage, the metacercaria, is ingested by a vertebrate host, the parasite excysts inside the intestine. It subsequently migrates to the liver, where it feeds on parenchymal cells, causing profuse hemorrhage. In about two months, the fluke reaches maturity and attains sexual maturity in the bile ducts. It is hermaphroditic and can fertilize itself (Mas-Coma *et al*., 2009). On completion of another week of development, each adult fluke starts laying eggs. These unembryonated eggs are secreted through the bile ducts to the intestine and ultimately are eliminated in feces. For the continuation of its life cycle, the eggs need to reach freshwater, where they develop and hatch. This hatching usually takes place within 10 to 15 days, but lower temperatures can cause it to be greatly prolonged (Hurtrez-Boussès *et al*., 2001). After hatching, the active motile ciliated miracidium actively searches for a proper snail host. After it infects a host, it invades the tissues of the snail and reproduces asexually. The miracidium goes through a series of developmental stages inside the snail, developing into sporocysts and rediae, each developmental stage increasing the number of immature flukes (Hurtrez-Boussès *et al*., 2001; Lalor *et al*., 2021). The rediae go on to give rise to cercariae, which exit the snail and invade the water environment. These cercariae settle on water plants or, less frequently, float in the water, encysting as metacercariae. These encysted forms are very resistant to small environmental variations and can last until ingested by a new definitive host (Hurtrez-Boussès *et al*., 2001).

Geological distribution

Global human infections are reported in those regions with heavy rainfall, waterlogged areas and irrigated paddocks (Graevenitz and Zahner, 2003). Sub-regions include South America, South East Asia, Africa, the Middle East, Europe, and the Pacific region. They are particularly widespread in regions of residence of freshwater snails because these are intermediate hosts of the trematode, as well as regions that have cattle or sheep grazing (Kaplan, 2001).

Water contamination and transmission

Water contamination is an important aspect in the spread of *F. hepatica*, which is a parasitic liver fluke. The lifecycle of the parasite includes freshwater snails as an intermediate host, and infected water may contain these snails, spreading the parasite (Abdullah, 2023). Here we discuss how *F. hepatica* spreads through water at different stages of its life cycle.

- Eggs: Eggs of *F. hepatica* may live in water for weeks to months, depending on the environmental conditions (Angles *et al*., 2022).
- Cercariae: The cercariae, which develop from infected snails, can also live in water for a few days to weeks, thus raising the risk of transmission (Rondelaud *et al*., 2023).
- Streams and rivers: Stagnant or slow-moving water bodies can carry infected snails and pollute the water with eggs and cercariae of the parasite (Rondelaud *et al*., 2023).
- Ponds and lakes: These water bodies can be contaminated, especially if they are being used for irrigation or as drinking water (Caravedo and Cabada, 2020).
- Irrigation canals: Irrigation water can be contaminated with eggs and cercariae of the parasite, and is a threat to humans and animals. Sources of drinking water: Contaminated sources of drinking water, like wells or springs, can also spread the parasite (Caravedo and Cabada, 2020).

Human behavior

The construction of irrigation and drainage canals led to the spread of lymnaeid snails and, as a result, to a greater incidence of fascioliasis. In contrast to irrigation canals that always carry water, drainage canals may dry up; therefore, there is no characteristic aquatic vegetation. Nevertheless, lymnaeids survive both habitats since they tolerate extreme droughts. Lymnaeid species are amphibious (Ngcamphalala *et al*., 2022). *Galba truncatula* and *G. cubensis* can survive in arid environments by partially or fully burrowing into the ground. The autonomous government of Castilla y León in Spain has financed the setting up of an advanced irrigation system since 1990 to stimulate new crops (Goumghar *et al*., 2001). Artificial alterations to the environment have facilitated the formation of new habitats for intermediate hosts and have promoted the development of fascioliasis. These findings demonstrate that such constructions cause a greater sanitary risk. Nevertheless, irrigation-system management can be integrated with other parameters, which can lengthen the exposure time of infection (Sabourin *et al*., 2018). For instance, in Pakistan, the first yearly peak of fascioliasis is linked to artificial irrigation, but the second peak is rainfall-driven. Despite some knowledge about how irrigation-system management favors snail breeding and thus enhances the prevalence of fascioliasis, few studies have been conducted before and after the installation of irrigation (Afshan *et al*., 2014). Preliminary epidemiological studies before construction must be conducted to assess the epidemiological risks of any man-made irrigation (Sabourin *et al*., 2018).

Fascioliasis dynamics

Fascioliasis is a very pathogenic zoonotic disease that has appeared in recent decades, partly because of the influence of climate and global changes. South America is the continent showing more extensive human Fascioliasis endemic regions and the greatest *F. hepatica* infection prevalence and intensities reported in humans (Bargues *et al*., 2017; Ogunmiloro, 2022). These severe public health situations seem primarily associated with mountain regions in Andean nations, while lowland regions of non-Andean nations, including Uruguay, report only occasional human cases or outbreaks. To elucidate this contrast, we compared *F. hepatica* from cattle and horses and Uruguay's lymnaeids by ribosomal DNA ITS-2 and ITS-1 spacers and mitochondrial DNA cox1, nad1, and 16S gene sequencing (Bargues *et al*., 2017; Mas-Coma *et al*., 2014). Results show that vectors are of *Lymnaea neotropica* rather than of *L. viator*, as previously always reported from Uruguay. Our association of fasciolid and lymnaeid haplotypes with previous records of the introduction and expansion of livestock species into Uruguay permits the understanding of the molecular diversity found (Bargues *et al*., 2017). We investigate the life cycle and transmission characteristics of *F. hepatica* by *L. neotropica* of Uruguay under controlled experimental conditions to facilitate comparison with the transmission potential of *F. hepatica* by *G. truncatula* at very high altitude in Bolivia (Bargues *et al*., 2017; Honer and Vink, 1963). Results indicate that while *L. neotropica* is an extremely efficient vector in lowlands; its transmission potential is significantly lower than that of *G. truncatula* in highlands. On this background, we examine the human fascioliasis cases registered in Uruguay and evaluate the current and future risk of human infection in the face of future climate change projections (Bargues *et al*., 2017; Siles-Lucas *et al*., 2021).

Climate conditions

Climate change impacts the transmission of Fasciola hepatica by temperature and rainfall regimes, affecting intermediate snail hosts and the parasite lifecycle. Research indicates that 10 °C to 25°C temperatures and high humidity conditions favor the development of parasites and the survival of snails (Fox *et al*., 2011; Modabbernia *et al*., 2024). Research in Sweden revealed that *F. hepatica* spatial distribution in beef cattle herds is governed by multifactorial effects, such as climate, soil type, and land cover (Novobilský *et al*., 2014, 2015). A study conducted in England and wales indicated that rainfall and temperature are significant predictors of *F. hepatica* infection, in addition to soil structure and minerals. Identified lack of coniferous forest, beef cattle herd density, certain soil types, and iron concentration in soil as significant predictors of *F. hepatica* infection (McCann *et al*., 2010). Moreover, predicting impacts of climate change on *F. hepatica* risk forecasted enhanced fascioliasis risk in the UK with shifting seasonal patterns and record high levels by 2070. Acute outbreaks and control strategies are also predicted by the Ollerenshaw index (Novobilský *et al*., 2015).

Control

There are many methods to control *F. hepatica* submission, and some of them are discussed here:

- Snail control: Population control of intermediate host snails can decrease transmission of *F. hepatica* (Lu *et al*., 2018).
- Anthelmintic therapy: Anthelmintic treatment can be used strategically to manage *F. hepatica* infections in livestock (Wanja *et al*., 2020).
- Vaccination: There is research being conducted to create effective vaccines against *F. hepatica* (McManus and Dalton, 2006).
- Awareness and education: Informing farmers, veterinarians, and the population at large on the risks and prevention methods of *F. hepatica* can decrease the prevalence of infection (Rokni *et al*., 2014).

Several drugs that are effective against *F. hepatica* can be used, including:

- Triclabendazole: A derivative of benzimidazole that is used extensively to treat fascioliasis in animals and humans (Brennan *et al*., 2007).
- Closantel: A compound of the salicylanilide class effective against *F. hepatica*, especially in veterinary practice (Biersack, 2024).
- Oxyclozanide: A salicylanilide derivative employed for the treatment of *F. hepatica* infections in livestock (Keiser and Utzinger, 2007).
- Nitroxynil: A nitrophenol derivative active against *F. hepatica*, especially in veterinary use (Keiser and Utzinger, 2007).

CONCLUSION

F. hepatica, a significant zoonotic parasite, relies on a complex interplay of hosts, environmental conditions, and human activities for its transmission. Freshwater snails and vegetation serve as critical intermediaries in its lifecycle, while contaminated water sources amplify its spread. Climate factors like temperature, rainfall, and humidity heavily influence the parasite's distribution and prevalence, making fascioliasis a growing public health concern in regions with favorable conditions, such as South America, Southeast Asia, and Africa. Effective control measures, including snail population management, improved water hygiene, education, and strategic use of anthelmintics like triclabendazole, are essential to mitigate infection risks. Understanding the lifecycle of *F. hepatica* and transmission dynamics is crucial for designing preventive strategies, especially as climate change exacerbates its spread and persistence.

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NOVELTY STATEMENT

This review highlights the integrated role of intermediate snail hosts, climatic conditions, water contamination, and human activities in shaping the transmission dynamics of Fasciola hepatica. By synthesizing updated global research, the study emphasizes how environmental change and agricultural practices collectively influence disease spread and risk patterns.

AUTHOR'S CONTRIBUTION

Rida Shahzad conceptualized the study and drafted the initial manuscript. Javeria Rasheed contributed to literature review, data organization, and revision of key sections. Shamaila Irum reviewed the scientific content, refined the structure, and approved the final version of the manuscript. All authors read and approved the final manuscript.

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Conflict of interest

The authors have declared no conflict of interest.

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