Evaluation of Helminth Infections Identified in Slaughtered Livestock in Iran, 2015-2019

Behzad Kiani
Mashhad University of Medical Sciences

Christine M. Budke
Texas A&M University College Station

Ebrahim Shams Abadi
Islamic Azad University Sabzevar Branch

Soheil Hashtarkhani
Mashhad University of Medical Sciences

Amene Raouf Rahmati
Mashhad University of Medical Sciences

Mostafa Akbarpour
Mashhad University of Medical Sciences

Mehdi Zarean
Mashhad University of Medical Sciences

Bibi Razieh Farash Hosseini
Mashhad University of Medical Sciences

Fatemeh Kiani
Mashhad University of Medical Sciences

Elham Moghaddas (✉ moghaddase@mums.ac.ir)
Department of Parasitology and Mycology, School of Medicine, Mashhad University of Medical Sciences, Mashhad, Iran

Research article

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Abstract

Introduction: Helminth infections of livestock can result in considerable economic losses. This study aims to evaluate the spatial frequency of cystic echinococcosis (CE), dicrocoeliasis, and fascioliasis in livestock slaughtered in Iran during the years 2015-2019 and estimate direct costs associated with organ condemnation due to these parasites.

Methods: Abattoir data from all 31 Iranian provinces were collected from the Iran Veterinary Organization. Infection prevalence was calculated per year at the province level. The Local Moran’s I statistic was performed to evaluate spatial autocorrelation of animals positive at slaughter for the years 2015-2019. Direct costs associated with condemned livers were calculated for each parasitic condition.

Results: Overall prevalence values for the study timeframe were as follows: sheep and goat fascioliasis (1.5%, 910,282/58,393,349), cattle fascioliasis (3.8%, 23,3175/6,038,419), sheep and goat dicrocoeliasis (4.6%; 270,1274/58,393,349), cattle dicrocoeliasis (3.1%; 186,009/6,038,419), sheep and goat CE (5.3%; 3,108,767/58,393,349), and cattle CE (7.2%; 438,534/6,038,419). Northwestern Iran had the highest prevalence of CE and fascioliasis. High infection areas for Dicrocoelium spp. included the provinces of Zanjan, Gilan, Qazvin, and Tehran, which are located in northern Iran. Direct economic losses for sheep and goat fascioliasis, dicrocoeliasis, and CE for the study period were US$13,841,826, US$41,768,472, and US$22,801,296, respectively. Direct economic losses for cattle fascioliasis, dicrocoeliasis, and CE for the study period were US$1,989,582, US$1,669,289, and US$2,656,535, respectively.

Conclusion: Our findings provide valuable data for future monitoring of these important parasitic diseases in Iranian livestock. Disease control strategies are required to reduce the economic and public health impact of these helminths.

Introduction

Livestock products provide an important source of protein for people worldwide [1]. Helminth infections are common in livestock and can result in economic losses to the livestock industry [2,3]. Parasite infections can lead to decreased growth, weight, and fertility, which can impact the production and/or quality of meat, milk, and hide/wool [4,5]. For example, financial losses due to fascioliasis in livestock are estimated to total US$ 3 billion per year globally [6].

Fascioliasis and dicrocoeliasis are two of the most common zoonotic helminth diseases of domestic livestock and both are included on the World Health Organization's (WHO) list of important human foodborne infections [7,8]. These trematodes are found in the gallbladder and bile ducts of ruminants such as sheep, cattle, and goats [9]. Humans can also become infected via inadvertent ingestion of metacercariae on aquatic plants (Fasciola spp.) or in ants (Dicrocoelium spp.) [10,11]. A systematic review estimated a fascioliasis pooled prevalence of 6.2% (95% CI: 5.8-6.5%) in Iranian livestock, with prevalence values of 3.1% (95% CI: 2.4-3.7%) in goats, 4.2% (95% CI: 3.8-4.5%) in sheep, and 9.0% (95% CI: 8.0-9.9%) in cattle [12]. In northern Iran, large-scale human fascioliasis occurred in 1989 that was the onset of the first largest outbreak of human fascioliasis in the world, involving up to 10000 individuals in Guilan Province. In 1999, the second outbreak that happened about 5000 infected people in the same region. Also, in 2000, there were a reported 1,306 cases of human fascioliasis in the province of Gilan [13].

Dicrocoeliasis is known to be quite common in Iranian livestock. Between 2015 and 2018, 2.9% of 571,991 slaughtered sheep and goats and 0.8% of 80,001 slaughtered cattle were positive for D. dendriticum in Tehran Province [14]. Human dicrocoeliasis occurs sporadically in Iran, with only five cases reported in the literature [15].

Cystic echinococcosis (CE), due to infection with the larval form of Echinococcus granulosus senu lato, is a globally important disease caused by zoonotic cestodes that cycle between canid definitive hosts and a variety of livestock intermediate hosts. Humans can act as aberrant intermediate hosts through ingestion of parasite eggs found on infected dogs, contaminated vegetables, or in water [16]. Hydatid cysts can be observed in various parts of the body, but are most commonly found in the liver and lungs [17]. CE is considered an endemic disease in Iran, especially in rural communities [18]. Between 1995 and 2014, 8,518 cases of human CE were recorded in different provinces of Iran, with the largest number of cases from Razavi Khorasan Province. The average annual number of human cases was 277 for this time period [19]. Between 1990 and 2015, a study found that 5.9% of sheep, 8.8% of cattle, and 6.4% of goats in Iran had CE at the time of slaughter [20]. An additional study conducted in Tehran...
Province, found that 2.5% of 571,991 slaughtered sheep and 2.2% of 80,001 slaughtered cattle had CE between February 1, 2015, and January 31, 2018 [14]. The objective of the current study was to determine the province-level prevalence, spatial distribution, and direct economic impact of livestock infections with Fasciola spp., Dicrocoelium spp., and E. granulosuss s.l. in Iran for the years 2015-2019.

Materials And Methods

Data collection and infection prevalence

Sheep are the most common livestock in Iran, followed by goats, and cattle. In April 2020, there were approximately 4,900,000 cattle, 47,300,000 sheep, and 17,000,000 goats in Iran (https://www.amar.org.ir), with the highest livestock populations in the northwestern part of the country (Figure 1) [21]. This retrospective study was conducted by using data from the Iran Veterinary Organization, which is a central repository for all abattoir-based data. In the current study, data from 2015 to 2019 were assessed from all 31 Iranian provinces. The data included total number of slaughtered cattle, sheep, and goats by abattoir location as well as fascioliasis, dicrocoeliasis, and CE infection status. The reporting system does not allow multiple parasitic infections to be recorded for a single animal. Therefore, animals infected with more than one parasite would only contribute to prevalence estimates for one of the infecting parasites. Infection prevalence was obtained by evaluating the number of positive animals divided by the number of animals slaughtered per year.

Spatial analyses

Descriptive maps of the prevalence of animals infected with Dicrocoelium spp., Fasciola spp., and E. granulosus s.l. were created for the years 2015-2019 using natural break classification, with five classes. Natural break classification is a data grouping method designed to determine the best arrangement of values into different classes. This is conducted by seeking to minimize each class's average deviation from the class mean, while maximizing each class's deviation from the means of the other groups. In other words, the method seeks to reduce the variance within classes and maximize the variance between classes [22].

The Local Moran's I statistic was performed to quantify spatial autocorrelation of prevalence at the provincial level. This test calculates a z-score and p-value to determine whether the apparent similarity (a spatial clustering of either high or low values) or dissimilarity (a spatial outlier) is more pronounced than one would expect in a random distribution. The null hypothesis states that prevalence values are randomly distributed across the study area. High-high and low-low regions indicate that the target area is encompassed by regions with similar prevalence values, while high-low and low-high regions show that the target area is encompassed by regions with dissimilar prevalence values [23]. In other words, the high-high and low-low areas indicate clusters of prevalence at a certain level [24]. ArcGIS 10.5 was used for space-time analyses.

Economic impact

Direct costs associated with offal condemnation due to fascioliasis (liver), dicrocoeliasis (liver), and CE (liver and/or lungs) were estimated. An animal with CE cysts in both the liver and lungs would contribute both organs to the economic estimate, but would only be considered once for evaluation of CE prevalence. The average price of liver and lungs were acquired from the Meisam abattoir in Tehran for the years 2015-2019, with the assumption that there is little variation in price countrywide. These values were then multiplied by the number of condemned organs per year. Costs were converted from the Iranian rial to the US$ for each study year using the free exchange rate (https://en.wikipedia.org/wiki/Iranian_rial).

Results

Parasite infection prevalence

In total, 3.8% (233,175/6,038,419) of slaughtered cattle and 1.5% (910,282/58,393,349) of slaughtered sheep and goats where infected with Fasciola spp. from 2015-2019. Annual prevalence of cattle fascioliasis ranged from 3.2% in 2019 to 3.9% in 2015, while the annual prevalence of sheep and goat fascioliasis ranged from 1.2% in 2015 to 1.6% in 2019 (Figure 2). The highest
number of cases of fascioliasis where in the provinces of Ardabil and East Azerbaijan, which are located in northwestern Iran (Additional File 1).

In total, 3.1% (186,009/6,038,419) of slaughtered cattle and 4.6% (270,1274/58,393,349) of slaughtered sheep and goats where infected with *Dicrocoelium* spp. from 2015-2019. Annual prevalence of cattle dicrocoeliasis ranged from 2.7% in 2019 to 3.0% in 2015, while the annual prevalence of dicrocoeliasis in sheep and goats ranged from 3.7% in 2015 to 4.8% in 2019 (Figure 2). The majority of cases of dicrocoeliasis were found in northern Iran (Additional File 2).

In total, 7.2% (438,534/6,038,419) of slaughtered cattle and 5.3% (3,108,767/58,393,349) of slaughtered sheep and goats were infected with *E. granulosus* s.l. from 2015-2019. Annual prevalence of cattle CE ranged from 5.9% in 2015 to 9.2% in 2019, while the annual prevalence in sheep and goats ranged from 4.0% in 2015 to 6.1% in 2019 (Figure 2). The majority of CE cases were found in northern Iran (Additional File 3).

**Spatial analysis**

The provinces of East Azerbaijan, West Azerbaijan, and Ardabil, which are all located in northwestern Iran, exhibited high-high cluster patterns for cattle fascioliasis. East Azerbaijan was also identified as a high-risk area for sheep and goat fascioliasis (Figure 3). Dicrocoeliasis was most common in the northern provinces of Zanjan, Gilan, Qazvin, and Tehran (Figure 4). The northern provinces of Isfahan, Chaharmahal, and Bakhtiari exhibited high-high cluster patterns for cattle CE, while sheep and goat CE was common in northwestern Iran (Figure 5). The local Moran’s index values and P-values for the maps presented in Figures 3-5 are shown in Additional File 4.

**Economic impact**

A total of 233,175 cattle livers and 910,282 sheep and goat livers were discarded due to fascioliasis during 2015-2019. These losses resulted in direct cost estimates of US$ 1,989,582 for cattle and US$ 13,841,826 for sheep and goats. During this same time period, 186,009 cattle livers and 2,701,274 sheep and goat livers where condemned due to dicrocoeliasis, resulting in losses of US$ 1,669,289 and US$ 41,768,472, respectively. In addition, 311,982 cattle livers and 1,500,385 sheep and goat livers were discarded due to CE, resulting in losses of US$2,573,851 and US$20,555,274, respectively. Furthermore, 126,602 cattle lungs and 1,608,382 sheep and goat lungs were discarded due to CE, resulting in losses of US$69,659 and US$2,203,488, respectively. These condemnations resulted in an estimated direct loss of US$ 84,727,000 due to the three parasitic infections over the five-year period (Table 1).

**Discussion**

This is the first spatial analysis of fascioliasis, dicrocoeliasis, and CE prevalence in slaughtered livestock for the entire country of Iran. Slaughtered cattle and small ruminants were more commonly infected with CE compared to the other evaluated parasites during the study timeframe. CE is endemic in the Middle East, with a recent systematic review calculating a weighted prevalence of 15.6% (95% CI = 14.2 – 17.1%) in livestock (cattle, sheep, goats, buffalos, camels, donkeys, and boars) and 4.2% (95% CI = 3.0 – 5.5%) in humans from Iran [20]. The mean annual prevalence values for CE in cattle (5.3%) and sheep and goats (7.2%) reported in the current study align with findings from Khalkhali et al. (2018) who reported a prevalence of 8.8% in cattle, 5.9% in sheep, and 6.4% in goats in Iran [20]. We identified high CE prevalence values in the northwestern region of the country, with much lower values in southern Iran. These distributions align with reported high prevalence values for human CE in northern (9%, 95% CI: 4-18%) and western (6%, 95% CI: 3-11%) Iran [25].

Porous international borders make it difficult to control importation of livestock infected with CE, especially when neighboring countries continue to have problems with the parasite. CE prevalence in cattle and small ruminants was found to be 8.0% and 8.9% respectively, in Pakistan [26]. In Iraq, 30% of cattle and 32% of small ruminants were found to be infected with CE [27]. Very limited information is currently available from Afghanistan and Turkmenistan. However, they are both also believed to be endemic for *E. granulosus* [28].
Dicrocoeliasis was the second most prevalent parasite found in this study, which aligns with other abattoir-based surveys conducted in Iran [29,30]. It is believed that *Dicrocoelium* spp. eggs can survive for a longer time on pastures compared to the eggs of *Fasciola* spp. Based on the data presented here, high infection areas for *Dicrocoelium* spp. were identified in northern Iran. A study focused on predating the spatial distribution and environmental suitability for *Dicrocoelium* spp. identified the littoral of the Caspian Sea as a high-risk area, with regional prevalence values of 36.7% and 6.1% for sheep and cattle, respectively [31]. A temperature range of 10–25°C and high levels of moisture are needed for the development of both *Fasciola* larvae and its intermediate snail host (*Lymnaea truncatula*) [32]. Over the past decade, Iran has experienced a prolonged and severe drought [33]. At present, the northern, northwestern, and western regions of Iran appear to be most suitable for completion of the *Fasciola* spp. life cycle [34,35,12]. Spatial analysis confirmed that northwest Iran was a high prevalence region for fascioliasis. Use of spatial analysis is helpful to highlight regions of concern and to help plan control initiatives.

CE (liver and/or lung infection) was the most prevalent evaluated parasitic infection in slaughtered Iranian livestock, but economic losses were greatest for dicrocoeliasis since the price of liver is approximately 12 times the price of lung. Although few economic assessments have been performed to evaluate costs due to dicrocoeliasis, *D. dendriticum* was responsible for 26% of marketable organ condemnation due to parasite infection in the region of Trikala, Greece. However, since only a small percentage (0.26%) of organs were condemned due to parasitic infections in this region of Greece, the economic impact was negligible [36]. Annual economic losses due to cattle fascioliasis in Iran were estimated to be 28.9 and 9.2 times the losses recorded in Nigeria (US$13,773) and Ethiopia (US$43,024), respectively [37,38]. Annual economic losses due to cattle CE were estimated to be 9.1 times the losses in Ethiopia (US$ 58,114) and 7.3 times the losses in Australia (US$ 66,893) [39,40].

The study did have some limitations, including the inability to account for infection with more than one parasite. In addition, CE cysts located in organs other than the liver and lungs were likely missed. Therefore, prevalence values may be underestimated. Also, only direct costs were evaluated. These parasitic conditions likely have additional impacts on animal growth and other production measures, which were not assessed in this study. Overall, the prevalence of these three parasites either appears to have remained steady or increased (e.g., cattle CE) between 2015 and 2019. Since these parasites are potential human health hazards, special attention should be given to their control [41].

**Conclusion**

This study has shown that helminth infections continue to be prevalent in Iranian livestock and result in substantial economic losses. These values reinforce the necessity of developing effective control programs based on regional needs.

**List Of Abbreviations**

cystic echinococcosis (CE)

**Declarations**

**Ethics approval and consent to participate**

The study was approved by the ethics committee of the Research Department of Mashhad University of Medical Sciences protocol number: IR.MUMS.MEDICAL.REC.1398.130.

**Consent for publication**

Not applicable

**Availability of data and materials**

The datasets used and/or analysed during the current study are available from the corresponding author (E.M) on reasonable request.

**Competing interests**
The authors declare that they have no competing interests.

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**Authors’ contributions**

Study design, analyse and interpretation of data: B.K, E.M, S.H and C.B; drafting of the manuscript: E.M, B.K and C.B; critical revision of the manuscript for important intellectual content: C.B, B.K and E.M; statistical analysis: B.K and S.H and F.K; Data gathering and cleaning: E.SA, A.RR, M.A, M.Z, F.K and BR.HF. The author(s) read and approved the nal manuscript.

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Tables

Table 1: Direct costs (in US$) associated with livestock infection with fascioliasis, dicrocoeliasis, and CE in 31 Iranian provinces, 2015-2019.
| Year | Number of condemned livers | Number of condemned lungs | Cost (US$) |
|------|---------------------------|--------------------------|------------|
| 2015 | Cattle fascioliasis | 50,367 | 158,928 | 39,258 | 495,729 | 47,358 | 233,556 | 1,025,196 |
|      | Sheeps and goat fascioliasis | 28,416 | 293,555 | 321,971 |
|      | Cattle dicrocoeliasis | 598,564 | 3,408,890 | 466,544 | 10,633,027 | 635,560 | 5,310,312 | 21,052,897 |
|      | Sheep and goat dicrocoeliasis | 411,068 | 2,927,359 |
|      | Cattle CE | 233,556 | 1,025,196 |
|      | Sheep and goat CE | 1,025,196 |
|      | Total infections | 5,843,107 |
| 2016 | Number of condemned livers | 47,479 | 222,568 | 53,337 | 695,224 | 47,591 | 290,481 | 1,356,680 |
|      | Number of condemned lungs | 28,416 | 293,555 | 321,971 |
|      | Cost (US$) | 598,365 | 5,000,157 | 672,192 | 15,618,730 | 702,390 | 6,927,359 | 29,519,193 |
| 2017 | Number of condemned livers | 54,782 | 206,655 | 34,674 | 592,604 | 86,517 | 393,890 | 1,369,122 |
|      | Number of condemned lungs | 38,073 | 372,481 | 410,554 |
|      | Cost (US$) | 469,560 | 3,160,605 | 297,205 | 9,063,355 | 757,474 | 6,283,751 | 20,031,950 |
| 2018 | Number of condemned livers | 47,634 | 182,990 | 30,339 | 497,118 | 66,883 | 294,405 | 1,119,369 |
|      | Number of condemned lungs | 20,049 | 340,404 | 360,453 |
|      | Cost (US$) | 201,121 | 1,355,481 | 128,098 | 3,682,355 | 300,389 | 2,303,322 | 7,970,766 |
| 2019 | Number of condemned livers | 32,913 | 139,141 | 28,401 | 420,599 | 63,633 | 288,053 | 972,740 |
|      | Number of condemned lungs | 31,412 | 248,052 | 279,464 |
|      | Cost (US$) | 121,971 | 916,693 | 105,250 | 2,771,005 | 260,722 | 1,976,552 | 6,152,193 |
| Total | Number of condemned livers | 233,175 | 910,282 | 186,009 | 2,701,274 | 311,982 | 1,500,385 | 5,843,107 |
|      | Number of condemned lungs | 126,652 | 1,608,382 | 1,734,984 |
|      | Cost (US$) | 1,989,582 | 13,841,826 | 1,669,289 | 41,768,472 | 2,656,535 | 22,801,296 | 84,727,000 |
Free exchange rates (Iranian rials to US$): 2015- 34,500 rials to 1 US$, 2016- 36,500 rials to 1 US$, 2017- 59,500 rials to 1 US$, 2018- 135,000 rials to 1 US$, and 2019- 170,000 rials to 1 US$ (https://en.wikipedia.org/wiki/Iranian_rial).