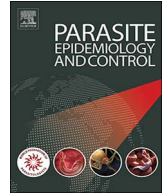




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Cystic echinococcosis in marketed offal of sheep in Basrah, Iraq: Abattoir-based survey and a probabilistic model estimation of the direct economic losses due to hydatid cyst

Mohanad F. Abdulhameed^{a,b,1}, Ihab Habib^{a,c,*}, Suzan A. Al-Azizz^b, Ian Robertson^{d,a}

^a College of Veterinary Medicine, School of Veterinary and Life Sciences, Murdoch University, Perth, Australia

^b College of Veterinary Medicine, University of Basrah, Basrah, Iraq

^c High Institute of Public Health, Alexandria University, Alexandria, Egypt

^d China-Australia Joint Research and Training Center for Veterinary Epidemiology, Huazhong Agricultural University, Wuhan, China

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ABSTRACT

Cystic echinococcosis (CE) is a highly endemic parasitic zoonosis in Iraq with substantial impacts on livestock productivity and human health. The objectives of this study were to study the abattoir-based occurrence of CE in marketed offal of sheep in Basrah province, Iraq, and to estimate, using a probabilistic modelling approach, the direct economic losses due to hydatid cysts. Based on detailed visual meat inspection, results from an active abattoir survey in this study revealed detection of hydatid cysts in 7.3% (95% CI: 5.4; 9.6) of 631 examined sheep carcasses. Post-mortem lesions of hydatid cyst were concurrently present in livers and lungs of more than half (54.3% (25/46)) of the positive sheep. Direct economic losses due to hydatid cysts in marketed offal were estimated using data from government reports, the one abattoir survey completed in this study, and expert opinions of local veterinarians and butchers. A Monte-Carlo simulation model was developed in a spreadsheet utilizing Latin Hypercube sampling to account for uncertainty in the input parameters. The model estimated that the average annual economic losses associated with hydatid cysts in the liver and lungs of sheep marketed for human consumption in Basrah to be US\$72,470 (90% Confidence Interval (CI); \pm 11,302). The mean proportion of annual losses in meat products value (carcasses and offal) due to hydatid cysts in the liver and lungs of sheep marketed in Basrah province was estimated as 0.42% (90% CI; \pm 0.21). These estimates suggest that CE is responsible for considerable livestock-associated monetary losses in the south of Iraq. These findings can be used to inform different regional CE control program options in Iraq.

1. Introduction

Livestock diseases can impact animal production and adversely affect the security of the human food supply chain. Added to that, many livestock diseases are zoonotic in nature and can infect humans via several routes. Parasitic zoonoses continue to pose serious concerns at the human-animal interface in many developing countries (McManus et al., 2003). Cystic echinococcosis (CE) is an important parasitic infection impacting both animal and public health, notably throughout the Middle East and North Africa. CE is caused by *Echinococcus granulosus*. Livestock (e.g. sheep, cattle, goats, and pigs) can acquire the infection indirectly from grass and

* Corresponding author at: Murdoch University, 90 South Street, Murdoch, Western Australia 6150, Australia.

E-mail address: i.habib@murdoch.edu.au (I. Habib).

¹ These authors contributed equally to this work.

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water contaminated by the eggs of *E. granulosus*, which are excreted with faeces of dogs (Craig et al., 2007; Deplazes et al., 2017). Human can become infected with CE accidentally by ingesting the eggs of *Echinococcus* through contaminated food and water, or from handling faeces of infected dogs, and other carnivores. Once ingested, the eggs hatch inside human's intestine, realising oncosphere larvae, which has a capability to penetrate the gut wall and then is conveyed by blood stream to different organs, mainly the liver and lungs where they settle and develop into cysts (McManus et al., 2003; Kebede et al., 2009). Worldwide, there may be in excess of 1 million people living with CE at any one time. Many of these people will be experiencing severe clinical syndromes which are life-threatening if left untreated (Craig et al., 2007).

CE in humans is most commonly found in rural communities and among people involved in raising sheep, as a result of the sheep's role as an intermediate host of the parasite and the presence of working dogs that are allowed to eat the offal of infected sheep. Ingested eggs can develop into the parasite's larval stage (metacestoda) in the livestock's internal organs (Brunetti et al., 2010). The hydatid cysts grow slowly, with minimal clinical signs observed in livestock animals, and typically are only discovered during routine meat inspection. In the majority of animals harbouring hydatidosis, the cysts are most commonly located in the liver and/or lungs (Craig et al., 2007).

The economic cost of CE in livestock can be divided into direct costs (mainly the loss of revenue through the condemnation of offal) and indirect costs (reduction in growth, fecundity and milk production of infected animals). At the abattoir, detecting hydatid cysts during routine meat inspection will lead to condemnation of the infested offal (mainly livers and lungs). Fertile cysts (with viable protoscoleces) in livestock offal are very important for continuation of the sheep-dog transmission cycle (Torgerson et al., 2003). A study in Jordan, estimated the annual loss of edible livers due to hydatidosis at around US\$850,000 annually (Torgerson and Dowling, 2001).

In Iraq, the small ruminant sector is very important for sustaining the country's food security. There are presently an estimated 7–8 million sheep in Iraq contributing a valuable source of meat, and providing income and job security to people working across the agricultural sector (Jarjees and Al-Bakeri, 2012; Thweni and Yassen, 2015). The fragile veterinary services in Iraq, after years of international economic sanctions and on-going political and ethnic conflicts, is very challenging for setting organized efforts to combat endemic livestock diseases. Various studies have reported the prevalence of hydatidosis in the livestock in different regions of Iraq (Jarjees and Al-Bakeri, 2012; Maktoof and Abu Tabeekh, 2015; Saida and Nouraddin, 2011; Thweni and Yassen, 2015). However, none of these studies considered a detailed estimation of the direct or indirect economic losses incurred by such endemic livestock disease. Estimation of such financial losses is largely handicapped by poor record keeping and reporting systems at abattoirs in Iraq, thus limiting the value of any economic evaluation using retrospective abattoir data. Added to that, in Iraq there are widespread informal butcherries with their on-site slaughter slabs, where freshly slaughtered meat and offal are sold directly to the public without any kind of meat inspection. Given the fact that informal meat markets are widespread in Iraq, they should be considered alongside with the formal meat market (where animals are slaughtered and inspected at an official abattoir) in order to enumerate the realistic economic impact of CE in sheep.

The sheep industry is an important segment of the agriculture sector in Basrah, the third largest province in Iraq (Maktoof and Abu Tabeekh, 2015). In this study, we conducted an active abattoir survey at the central abattoir of Basrah, located in the south of Iraq, to determine the abattoir based occurrence of hydatid cysts in sheep slaughtered for human consumption. In parallel to this active abattoir survey, we developed a probabilistic model to estimate the direct financial loss from offal condemnation due to hydatid cysts in slaughtered sheep. We interviewed local veterinarians and butchers to gather expert-opinions for populating some of the model variables. This model-based approach could be extended to other regions in Iraq, and might be applicable to similar developing country settings where the infrastructure of abattoir data collection system is lacking.

2. Materials and methods

2.1. Study setting

This study was conducted in Basrah province located in the south of Iraq. The total human population of Basrah province was estimated at 2,403,301 million according to the last census achieved in 2014. Basrah is situated in a desert-type environmental zone with a monsoon climate; the province is in a fertile agricultural region and contributes to the Iraqi agriculture sector through its large agricultural and livestock industries (Maktoof and Abu Tabeekh, 2015). The study was carried out over a period of six months (between May and October 2016), at the central governmental abattoir in Basrah province.

2.2. Post-mortem abattoir inspection and cyst viability examination

A cross-sectional survey was conducted at the abattoir in order to determine the prevalence, organ distribution, viability and economic implications of hydatid cysts in the slaughtered sheep. Both the meat inspection and laboratory work were carried out personally by the first author of this study. Regular visits (3 days per week) were made to the central governmental abattoir in Basrah. The visits were assured to be varying over different days of the week. On a given day, sheep were selected using a systematic selection sampling; the sheep were held in the loading pen and then were allowed to pass through a race to the slaughter floor. Every 5th animal was then selected as it passes through. In total 631 sheep were examined by detailed post-mortem inspection for the presence of hydatid cysts; this included visual inspection and palpation for hydatid cysts in visceral organs including the liver, lungs, spleen, heart and kidneys. All animals were from native flocks, and none were imported. The post-mortem examination procedure employed visual examination, palpation and systematic incision of each carcass and visceral organs, particularly the lung, liver, spleen, kidney

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