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Echinococcosis in humans and animals in Southern Africa Development Community countries: A systematic review

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ABSTRACT

The taeniid *Echinococcus* is the causative agent of the zoonotic disease echinococcosis/hydatidosis and is associated with economic losses in livestock production. This review summarizes available scientific literature on circulating species of *Echinococcus* in humans, wild and domestic animals in countries of Southern Africa Development Community, and identifies knowledge gaps and recommend research priorities. Data were systematically accessed from Google Scholar, MEDLINE/PubMed and from library resources from December 2017 to June 2019. Meta-analysis was conducted in STATA program and heterogeneity and prevalence values were pooled by host species with 95% confidence interval. In intermediate hosts, the overall prevalence of *Echinococcus* by meat inspection was 10% (CI: 9–11%) in small ruminants, 7% (CI: 5–8%) in cattle, 1% (CI: 0–1%) in pigs and 9% (CI: 0–29%) in wild herbivores. In canids by CoproAg-ELISA and necropsy the prevalence was of 10% (CI: 8–10%) and 6% (CI: 3–10%) respectively. A high level of heterogeneity ($I^2 > 65\%$) was observed for all study groups. *Echinococcus equinus*, *E. canadensis*, *E ortleppi* and *E. felidis* were reported from wildlife and *E. ortleppi*, *E. granulosus s. s.* and *E. canadensis* from humans. There is paucity of research in echinococcosis and gaps in prevalence reports over time in both humans and animals in the SADC region and we recommend an increase in future studies on the epidemiology of disease, risk factors for transmission in animals and humans and its relation with human health specially in the advent of HIV pandemic following a "One Health" approach.

1. Introduction

Cystic and alveolar echinococcosis caused by *Echinococcus* spp., an intestinal cestode belonging to family Taeniidae are zoonotic parasitic diseases among the list of 17 neglected tropical diseases (Craig et al., 2007; WHO, 2013a; Budke et al., 2017). The life cycle of the parasite involves domestic and wild canids as definitive hosts which are infected through the ingestion of viable hydatid cysts in infected viscera, in most cases the liver and lungs of intermediate hosts which comprise a wide range of mammalians including humans (Craig et al., 2017; Thompson, 2017).

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The disease is prevalent in poorly-resourced pastoralist populations who use dogs to look after their herds (Hotez et al., 2007; Molyneux et al., 2011; WHO, 2013b) especially in regions with poor sanitary conditions where slaughtering of livestock and game is conducted without veterinary inspection or supervision (Moro and Schantz, 2009; Rojas et al., 2014). It is also associated with immunocompromised individuals infected by human immunodeficiency virus (HIV) (Yang et al., 2009) and this is common in Southern Africa Development Community (SADC) countries where in addition to malaria, HIV indices represents one fifth of worldwide reported cases with most of them concentrated in South Africa (Mudambo, 2019; Delva and Karim, 2014). Cases of cystic echinococcosis (CE) in HIV patients have been reported in South Africa (Chopdat et al., 2007; Wahlers et al., 2011) and Mozambique (Noormahomed et al., 2014). Reviewed data from sub-Saharan Africa by Romig et al. (2011), Wahlers et al. (2012) and Romig et al. (2017) showed that the disease is uncommon in western and southern Africa and prevalent in East African countries with a considerable number of studies conducted in Kenya (Turkana), Ethiopia, northern Tanzania, Uganda and South Sudan.

Depending on the size and location of the cysts, clinical manifestations may vary in animals and humans due to its slow growth (Moro and Schantz, 2009). It may be asymptomatic and often be diagnosed accidentally either in humans or animals during procedures unrelated to the disease (Siles-Lucas et al., 2017).

Cestode eggs can be visualized in stool samples through copro-parasitological techniques, although cannot be differentiated from other Taeniidae (Thompson, 2017). Due to the intermittent shedding of eggs in the definitive host, purgatives such as arecoline hydrobromide can be used to recuperate adult tapeworms (Craig et al., 1995; Lahmar et al., 2007). Alternatively, conclusive results can be obtained during post-mortem examination of canids with the visualization and morphological identification of the adult tapeworm in the intestines during necropsy (El-Shehabi et al., 2000; Allan and Craig, 2006).

The visualization of hydatid cysts in humans can be made through imaging tools such as radiography, computed axial tomography (TAC), ultrasonography and magnetic resonance imaging (MRI) followed by microscopic visualization of protoscoleces in aspirates of vesicular fluid. Immunological assays such as the copro-Enzyme-Linked Immunosorbent Assay (Copro-ELISA) or enzyme-linked immunoelectrotransfer blot (EITB) can be used for detection of antigens or antibodies in both definitive and intermediate host (Ito and Craig, 2003). Furthermore, molecular techniques based on Polymerase Chain Reaction (PCR) are used to confirm species and differentiate genotypes involved (Bowles et al., 1992; Hüttner et al., 2008; Nakao et al., 2013a). To date, *Echinococcus* genotypes G1 to G10 are grouped into five species classified based on the analysis of mitochondrial and nuclear genome of *Echinococcus granulosus* (sensu lato) namely *E. felidis* (not referred to as genotype), *E. granulosus* sensu stricto (G1-G3), *E. equinus* (G4), *E. ortleppi* (G5) and *E. canadensis* with the forming clade G6/G7, G8 and G10 (Nakao et al., 2013b; Romig et al., 2015; Romig et al., 2017). The referred genotypes have a world-wide distribution with the exception of Northern arctic and boreal genotypes (G8 and G10) (Nakao et al., 2013a).

The aim of this study was to determine the prevalence of *Echinococcus* spp. through review of available literature on the parasite in wild, domestic animals and humans in SADC countries following a systematic approach and to identify knowledge gaps for future research.

2. Methods

2.1. Information source

The information presented in this review was structured in accordance to PRISMA guidelines (Moher et al., 2009). The literature was systematically accessed from Google Scholar, MEDLINE/PubMed and also from the library resources from University of KwaZulu-Natal (Westville campus) and Eduardo Mondlane University (Veterinary Faculty).

2.2. Literature search

The literature search was carried out in 15 countries belonging to the SADC namely Tanzania, Malawi, Democratic Republic of Congo, Madagascar, Mauritius, Seychelles, Zambia, Zimbabwe, Angola, Namibia, Botswana, Mozambique, South Africa, Lesotho and Swaziland (Gallinetti, 2008). The following search terms were used to access the literature by country: *Echinococcus*/echinococcosis OR hydatid/hydatidosis IN Tanzania OR Malawi OR Democratic Republic of Congo OR Madagascar OR Mauritius OR Seychelles OR Zambia OR Zimbabwe OR Angola OR Namibia OR Botswana OR Mozambique OR South Africa OR Lesotho OR Swaziland. Preselection of potential articles was made based on the title of articles, and if there was any evidence of eligibility according to the referred selection terms and/or matching with the inclusion criteria. The abstract was then accessed followed by a reading of the methodology and results. References from identified articles were scanned to identify literature not found by searching the mentioned electronic database. All selected references were stored in EndNote X8 database.

2.3. Inclusion and exclusion criteria

Studies which involved mass screening of *Echinococcus* infection in humans and animals were included providing the following information:

i. Prevalence of *Echinococcus* in SADC countries including the sample size and number of positives
ii. Diagnostic test applied

iii. Host and parasite species and
iv. Time period of study.

Studies were excluded if they did not meet the above mentioned criteria together with the following:

i. Review papers on echinococcosis/hydatid disease
ii. Studies reporting only positives by affected organs
iii. Studies reporting the parasite by immunological methods in intermediate hosts or when any other immunological method that is not CoproAg-ELISA was applied in dogs.

2.4. Quality of the studies

The following checklist was used to determine the quality score of the studies; i) description of research questions/objectives ii) prevalence of *Echinococcus* as the main objective of the study iii) sampling method described iv) period of study clearly stated v) diagnostic method stated and conclusive for *Echinococcus* vi) use of immunological, serological or molecular techniques vii) categorization of subjects (age, sex) viii) representativity of target sample in the general population ix) evidence of random selection of samples x) a minimum sample size determined. To evaluate the quality of each study, the following checklist was applied and given a score of 0 for "no", 2 for "yes" and 1 for "unknown". The score was expressed as a percentage calculated for each study by summing the score obtained across the items answered as "yes" and dividing by the total probable score of ten (10). The median quality score was determined for animals and humans and a study with a score above the median were classified as of "high" quality and studies with score below the median was classified as of "low" quality.

2.5. Data analysis

Heterogeneity among studies, pooled prevalences of *Echinococcus* spp. by animal group (dogs, wild animals, cattle, small ruminants, pigs and humans) and 95% confidence intervals (CI) were calculated and results of each group were expressed in forest plots in Stata with data exported from Microsoft Excel. Data generated from CoproAg-ELISA studies and direct visualization of parasite were analysed separately. Percentage of variation between studies were expressed by Inverse variance index (I^2), where values of 25%, 50% and 75% were classified as low, moderate and high degree of heterogeneity, respectively.

3. Results

Forty-eight articles met the selection criteria (Fig. 1) and were from ten out of fifteen SADC countries namely Tanzania, Democratic Republic of Congo, Madagascar, Zambia, Zimbabwe, Angola, Namibia, Mozambique, South Africa, and Swaziland. Articles comprised a mixture of retrospective and prospective studies in livestock (cattle, goats and sheep), dogs, wild animals and humans.

3.1. Pulled prevalences and heterogeneity

The overall prevalence of *Echinococcus* spp. in small ruminants (goat and sheep) by meat inspection was of 10% (CI: 9–11%), 7% (CI: 5–8%) in cattle, 1% (CI: 0–1%) in pigs and 9% in wild herbivores. In canids the prevalence was 10% (CI: 8–10%) by CoproAg-ELISA method and 6% (CI: 3–10%) by visualization of parasite (Figs. 2, 3 and 4).

3.2. Quality score and diagnostic techniques used in the studies

Quality of selected articles is presented in Tables 1 and 2 with score index ranging from 2 to 8 and median score of 4. With regard to the diagnostic methods applied we found that hydatid cysts from livestock were collected during meat inspection in 17 studies. In canid and felid host, we found six (6) studies where necropsy was applied, one (1) with purgative arecoline and two (2) with copro-ELISA method applied. In humans the parasite was detected by surgery in three (3) studies, by ultrasonography in two (2), and in one (1) by post-mortem examination. For case reports in humans, depending on cyst location, parasite confirmation was done through microscopic examination after imaging tests or surgery (Table 3).

3.3. Species and genotypes of Echinococcus reported in SADC countries

Circulating species of *Echinococcus* which have been reported from wildlife in SADC countries are *E. equinus*, *E. canadensis*, *E ortleppi* and *E. felidis* and in humans are *E. ortleppi*, *E. granulosus s. s.* and *E. canadensis* (Table 4).

4. Discussion

This review included reports of echinococcosis/hydatid disease in livestock, dogs, wild animals and humans from SADC countries from the period of 1934 to 2017 with the oldest study from South Africa (Ortlepp, 1934) and the most recent studies from Tanzania (Miran et al., 2017) and South Africa (Kloppers et al., 2019). ˜The lack of studies made it impossible to categorize

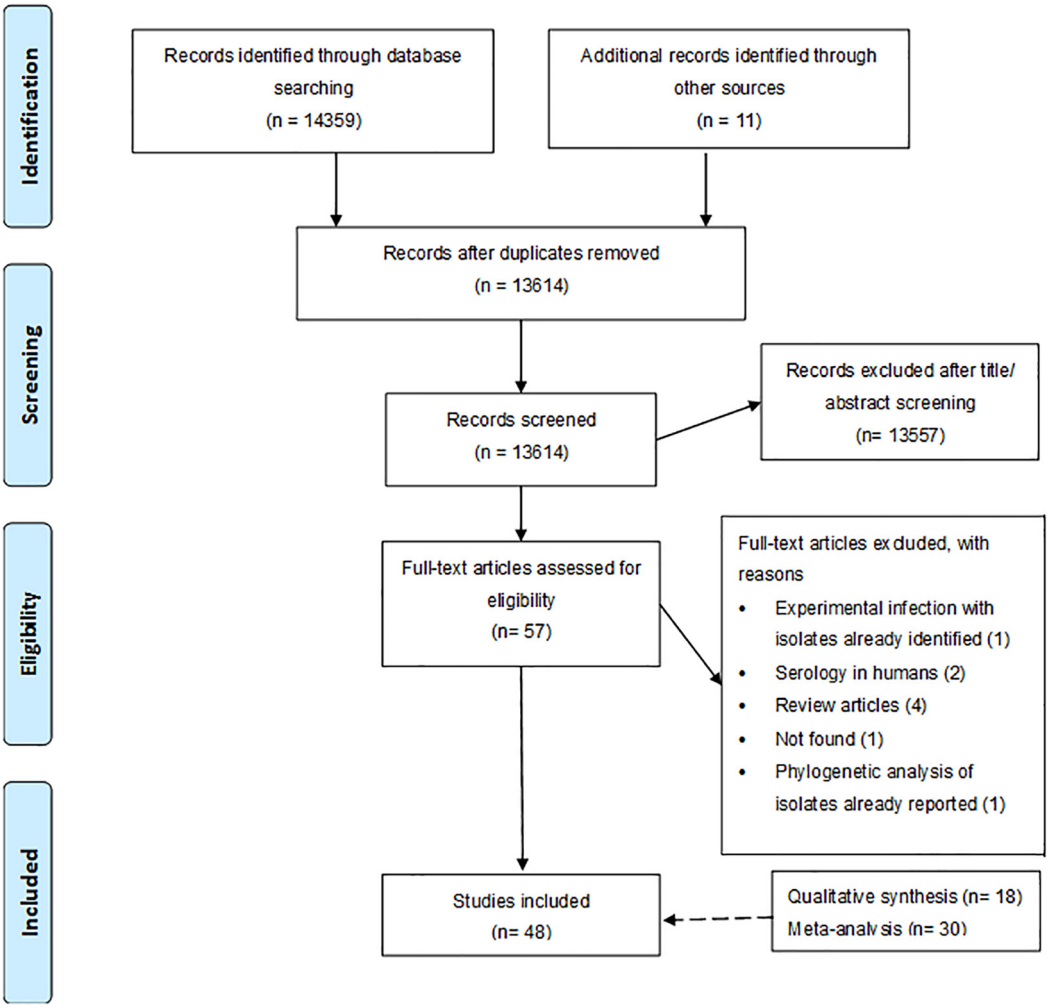

Fig. 1. Selection criteria of literature used in the present review.

prevalence values in designated time periods however, there was a tendency of increasing of values from 1980s and before to 2000s in livestock. The age of slaughtered animals may also have influence in the parasite detection since old animals are more likely to be positive due to cysts slow growth (Moro and Schantz, 2009). Intensity of contamination of pasture and water sources with the parasite eggs may also influence increasing parasite prevalence in livestock and this may be correlated with the presence of infected dogs circulating in the community with practices such as home slaughter, feeding dogs with raw meat and the lack of anthelmintic treatments in dog populations (Otero-Abad and Torgerson, 2013). However, risk factors related to the transmission of *Echinococcus* are not reported in studies included in this review and there is no evidence of programs aimed to control the parasite in the SADC which may justify the apparent rise in cases.

Prevalence values of 10% by CoproAg-ELISA and 6% by necropsy were detected in definitive hosts. These prevalences were lower than findings in necropsied dogs from East Africa in Kenya, Uganda and Sudan with values ranging from 33% to 66% (Saad and Magzoub, 1986; Buishi et al., 2006; Inangolet et al., 2010; Oba et al., 2016). In Nigeria and Libya, copro-antigens of *Echinococcus* were detected in 12.45% and 21.6% of tested dogs (Coulibaly and Yameogo, 2000; Buishi et al., 2005), values which were also higher than of the present review.

An average prevalence of 10% in small ruminants and 7% in cattle recorded in this review are similar to the values reported in East Africa by Saad and Magzoub (1986), however, slightly higher than findings by Mohamadin and Abdelgadir (2011), who found prevalence values ranging from 1.4% to 2.8%. In Kenya, prevalences of 10.8%, 16.5% and 25.8% in goats, sheep and cattle were reported (Addy et al., 2012) and this is high compared to values reported in SADC countries in this review. The large number of herding dogs and seasonal migration of nomadic pastoral communities in East Africa with their large herds for long periods, may contribute to the dispersion of parasitic forms in the explored grazing and water sources (Addy et al., 2012; Romig et al., 2017). Considering the circulation of wild animals in the same areas, there are also chances of contact between livestock and predators (Mohamadin and Abdelgadir, 2011). In West Africa, lower prevalence values were recorded compared to our study (less than 4.3%) in Burkina Faso and Nigeria (Coulibaly and Yameogo, 2000; Bala et al., 2011; Magaji et al., 2011).

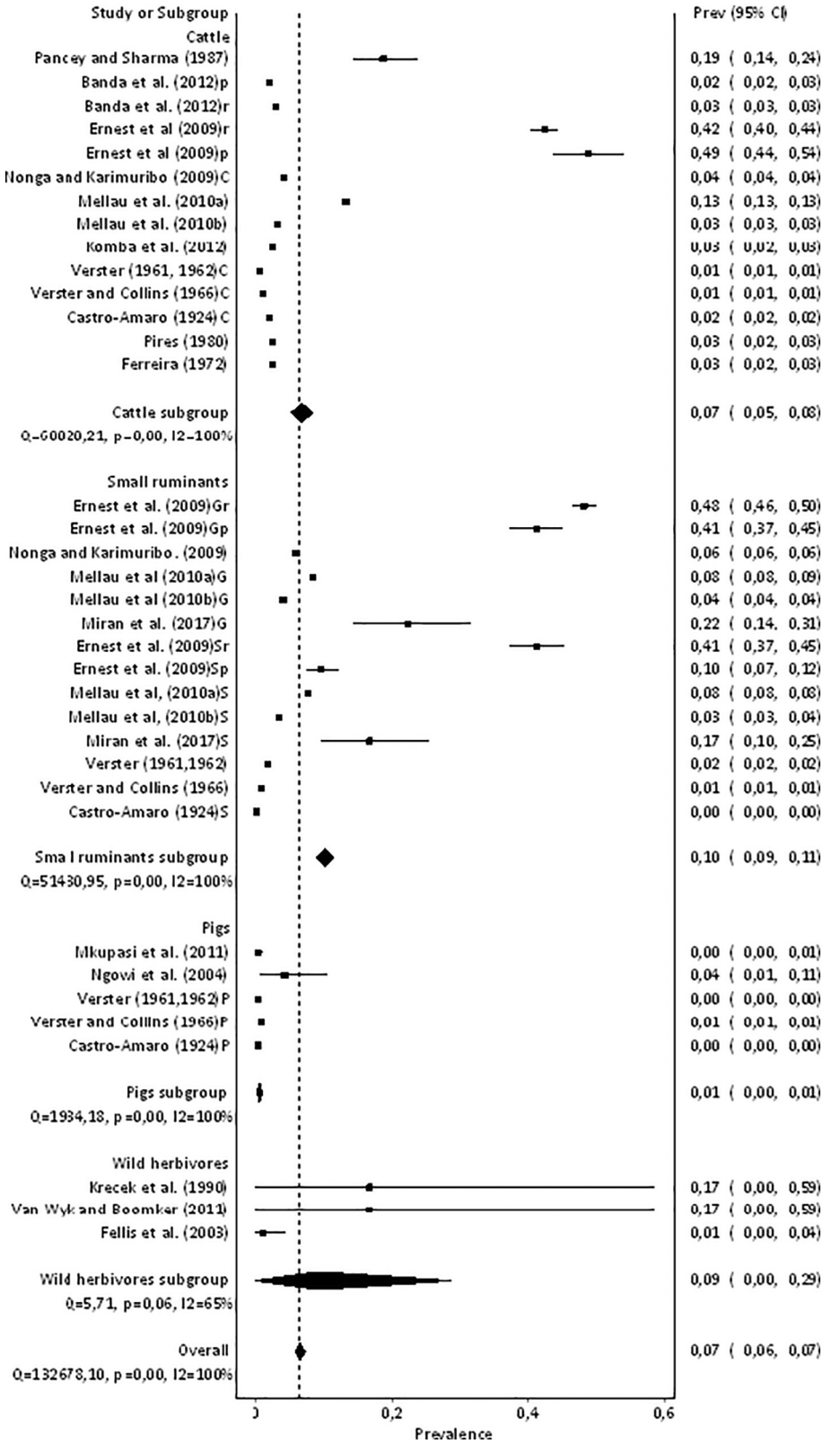

Fig. 2. Forest plot of prevalence estimates of *Echinococcus* spp. in domestic and wild animal intermediate hosts with random effects analysis in Southern Africa Development Community countries.

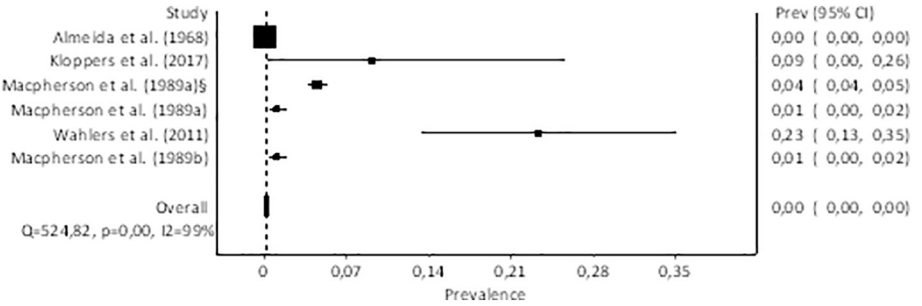

Fig. 3. Forest plot of prevalence estimates of *Echinococcus* spp. in humans by surgery with random effects analysis in Southern Africa Development Community countries.

In general, information on echinococcosis in pigs in sub-Saharan Africa is scarce (Wahlers et al., 2012) and compared to other livestock species, pigs were less reported to be infected by *Echinococcus* (Ndirangu et al., 2004) with exception of West Africa in the region of Delta of Niger where a prevalence of 56% was recorded (Arene, 1985) and the value was higher than the prevalence value of 1% (CI: 0–1%) of this study. Factors that may have contributed to the apparent low prevalence of hydatid disease are the few studies conducted in pigs and may also be due to the high significance given to cysticercosis caused by *Taenia solium* (Andriantsimahavandy et al., 1997; Mkupasi et al., 2011).

Compared with ruminants, few prevalence studies on echinococcosis have been conducted in humans in SADC countries. All of them were based on retrospective cases of hospital records and the disease was not primarily suspected due to the similarity of clinical manifestation with other conditions. High cost of reliable diagnostic tests (imaging tests and surgery) could be one of the reasons why this disease has been underdiagnosed in many of the SADC countries (Ernest et al., 2009).

In Turkana area of Kenya, besides of keeping the herds, young dogs are acquired by farmers to clean children and food utensils as a way of saving water (Watson-Jones and Macpherson, 1988; Macpherson et al., 1989a) constituting an important source for human infection. We were not able to ascertain from the review, the level of knowledge of pastoralists about the parasite, however in regions of Tanzania the disease is called “ngeto” in animals and “ngya” in humans (Macpherson et al., 1989a). As in Tanzania, probably in other countries the parasite may receive other designations and this fact may serve as a basis for advocating awareness in farming communities towards the control of this parasite with involvement of public health agents and veterinarians.

A high level of heterogeneity in all animal groups was verified. This may be due to differences in the high number of studies in slaughtered cattle and small ruminants published in Tanzania compared to other countries. Most of the referred studies were based on retrospective records and no sampling strategy was determined by authors and in this context, there was no indication of the representativeness of animals involved in studies. Characteristics within study groups (age, sex) and cultural habits were

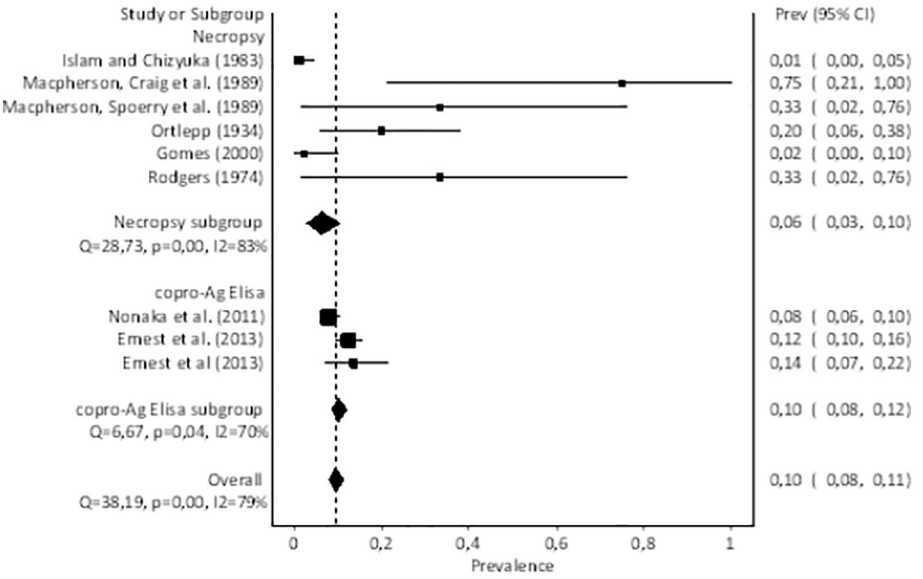

Fig. 4. Forest plot of prevalence estimates of *Echinococcus* spp. in canids by CoproAg-ELISA and necropsy with random effects analysis in Southern Africa Development Community countries.

Table 1
Prevalence of hydatid cysts/taenid eggs/*Echinococcus* spp. antigens in livestock, wildlife and canids in Southern Africa Development Community (SADC) countries (data from 1934 to 2018).

Study area	Host species	N	Np	(%)	Diagnostic test	Study period	Quality score	Index score	References
Zambia	Dogs	85	1	1.12	Necropsy	1980–1982	3	0.3	Islam and Chizyuka (1983)
	Cattle	268	50	18.65	Meat Inspection	1981–1982	5	0.5	Pandey and Sharma (1987)
	Dogs	540	43	7.96	CoproAg-ELISA	2005–2007	5	0.5	Nonaka et al. (2011)
	Cattle	4061	84	2.1	Coproscopy	2007–2008	8	0.8	Banda et al. (2013)
		158,456	4689	2.96	Meat inspection	1994–2007			
Namibia	Giraffe	6	1	17	Meat inspection	1985–1986	3	0.3	Krecek et al. (1990)
Tanzania	Dogs	4	3	75	Necropsy	1985–1987	7	0.7	Macpherson et al. (1989a)
		6	2	33.3	Arecoline				
	Pigs	70	3	4.3	Meat inspection	1997–1998	3	0.3	Ngowi et al. (2004)
	Panthera leo	6	2	33.3	Necropsy	1970	2	0.2	Rodgers (1974)
	Cattle	2677	1132	42.3	Meat inspection	1998–2001	6	0.6	Ernest et al. (2009)
	Goats	3047	1466	48.1					
	Sheep	607	58	9.6					
	Cattle	357	174	48.7					
	Goats	619	255	41.2					
	Sheep	105	67	63.8					
	Cattle	115,186	4861	4.2	Meat inspection	2005–2007	3	0.3	Nonga and Karimuribo (2009)
	Sheep/goat	99,401	5984	6.02					
	Cattle	115,185	15,245	13.2	Meat inspection	2005–2007	2	0.2	Mellau et al. (2011)
	Sheep	61,551	4768	7.7					
	Goat	37,850	3192	8.5					
	Cattle	115,185	3705	3.2	Meat inspection	2005–2007	2	0.2	Mellau et al. (2010)
	Sheep	61,551	2146	3.5					
	Goat	37,850	1538	4.1					
	Pigs	731	3	0.41	Meat inspection	2007–2008	3	0.3	Mkupasi et al. (2011)
	Cattle	30,713	799	2.60	Meat inspection	2010–2011	2	0.2	Komba et al. (2012)
	Dogs	442	55	12.4	Copro-ELISA		4	0.4	Ernest et al. (2013)
	Wild carnivores	88	12	13.6					
	Sheep	90	15	16.6	Meat inspection	2013	4	0.4	Miran et al. (2017)
	Goats	90	20	22.2					
South Africa	Dogs	25	5	20	Necropsy	1934	4	0.4	Ortlepp (1934)
	Cattle	4886 441	34,205	0.7	Meat inspection	1945–1960	5	0.5	Verster (1962, 1961)
	Goats, sheep	12,936 392	232,865	1.8					
	Pig	735,852	2943	0,4					
	Cattle	1,706,420	18,429	1.08	Meat inspection		5	0.5	Verster and Collins (1966)
	Goats, sheep	5,571,224	51,255	0.92					
	Pig	674,762	6613	0.98					
	Tragelaphus strepsiceros	96	1	1	Meat inspection	1981–1983	2	0.2	Fellis et al. (2003)
	Phacochoerus aethiopicus	6	1	16,6	Meat inspection	2006–2007	2	0.2	Van Wyk and Boomker (2011)
Swaziland	Cattle	5886	653	11.09	Meat inspection		2	0.2	Mitchell (1977)
Mozambique	Cattle	13,390	336	2.50	Meat inspection	1971–1972	2	0.2	Ferreira (1980)
	Dogs	643	0	0	Necropsy				
	Cattle	426,866	8951	2.09	Meat inspection	1948–1958	3	0.3	de Castro-Amaro (1960)
	Pigs	76,956	281	0.36					
	Sheep	92,028	120	0.13					
Angola	Dogs	42	1	2.4	Necropsy		2	0.2	Gomes (2000)

Np = number of positive.

not reported, however, these factors can affect the level of heterogeneity between studies including the difference in the geographical location and climate where these animals are being reared.

In wild animal intermediate hosts, studies carried out in Namibia and South Africa reported an overall prevalence of 9%. Only four publications reported the prevalence in slaughtered wild animals in the period of this study (Rodgers, 1974; Krecek et al., 1990; Fellis et al., 2003; Van Wyk and Boomker, 2011).

According to the reviewed information, the first molecular characterization study on *Echinococcus* in humans in SADC countries was from South African patients where *E. granulosus* sensu stricto (G1), *E. canadensis* (G6/7) and *E. ortleppi* (G5) were identified

Table 2
Cases of human hydatidosis reported in Southern Africa Development Community (SADC) countries (data from 1944 to 2018).

Study area	N	Np	%	Diagnostic test	Period	Score	Quality index score	References
Tanzania	959	10	1.0	Ultrasound	1985	7	0.7	Macpherson et al. (1989a)
	2749	122	4.4	Surgery	1968–1986			
	959	10	1.0	Ultrasound	1985–1987	5	0.5	Macpherson et al. (1989b)
Mozambique	52,400	10	0.02	Post-mortem	1944–1967	2	0,2	de Almeida et al. (1968)
South Africa	60	14	23.3	Biopsy	1995–2010	4	0.4	Wahlers et al. (2011)
	22	2	9.09	Surgery	2012–2017	2	0.2	Kloppers et al. (2019)

Table 3
Human case reports of hydatidosis in Southern Africa Development Community (SADC) countries (data from 1948 to 2018).

Country	Affected organ	Total cases	History of patient	Diagnostic methods	Treatment	Reference
South Africa	Kidney	1	38-year-old female emaciated with a large slightly movable swelling in the right fossa noticed 10 months before her first visit to the hospital	Microscope	Surgery and drain tube in the wound for 4 days	Villet (1948)
	Tongue	1	18-year-old female, farm laborer with painless swelling on the right side of tongue for 3 months affecting her speech	Cyst incision and macroscopic observation of germinal layer and brood capsules	No information	Perl et al. (1972)
	Liver + lungs	1	32-year-old Mozambican man HIV+, with a cough, hemoptysis and chest pain for 2 weeks	Radiography/computer tomography. Confirmation by indirect hemagglutination assay	4 cycles of albendazole 400 mg separate by 1-week intervals	Chopdat et al. (2007)
	Liver	2	7-year-old boy	Laparotomy	Irrigation of cyst cavity with 20% hypertonic saline solution	Krige et al. (2002)
	Spinal cord	3	6, 8 and 9-years-old children with limb weakness/loss of ambulation/hemiparesis	Magnetic resonance, histology and serology	Surgery	Ndondo et al. (2003)
	Brain + liver + lungs + mediastinum	1	19-year-old male who with nervous symptomatology	Radiology of chest, serology and computer tomography	Albendazole for 6 months	Ntusi and Horsfall (2008)
	Brain	14	3 children's 12-year-old female with headache, painful neck, torticollis	Computed tomography and serology/radiology and histology	Prednisone and praziquantel for 14 days/28 days of Albendazole	Copley et al. (1992)
			11 patients (9 females and 2 males) with age ranging from 3 to 12 years old from sheep farming areas of Namibia and south Africa. Clinical histories of intracerebral mass lesions, epilepsy and papilledema.	Computed tomography	Surgery and irrigation of cavity with saline/hydrogen peroxide Mebendazole 1 cycle and albendazole 2 cycles of 28 days	Peter et al. (1994)
	Maxillofacial region	2	20-year-old female with right submandibular swelling/6-year-old boy with swelling in the right cheek	Microscope examination/histopathology	Surgery and irrigation of wound with 1% solutions of peroxide and hypochlorite	Bouckaert et al. (2000)
	Heart	1	27-year-old male with history of syncope coming from a rural sheep farmer	Magnetic resonance, histopathology confirmation	Praziquantel and albendazole two days prior to surgery	Brecker et al. (2005)
Namibia	Heart	1	17-year-old asymptomatic boy from a rural sheep farm	Echocardiogram	Surgery and drain tube in the wound	Rossouw et al. (1992)
Zimbabwe	Left thigh	1	46-year-old female resident in a rural community with painful lump noticed 15 months before her first visit to the hospital	Histopathology confirmation	Surgery and irrigation of 5% sodium chloride for 3 days Albendazole 10 mg/kg daily for 8 days	Bordon et al. (1989)
	Lung	1	Rural sheep farm in childhood	–	–	Holmgren and Go (1971)
Democratic Republic of Congo	Liver	1	European patient diagnosed in 1958, was living in Congo since 1952	Radiology	Surgery	Pécarrère et al. (1994)
Madagascar	Article not found					De and Dardenne (1958)

Table 4
Molecular identities of isolates of *Echinococcus* spp. collected from selected Southern Africa Development Community (SADC) countries (data from 2004 to 2018).

Study area	Host species	N	Positive	Genotypes	Amplified gene	Reference
South Africa	Humans	32	32	*E. granulosus* s. s. (26) *E. canadensis* (5) G5 *E. ortleppi* (1)	*nad1*, *12S rRNA*	Mogoye et al. (2013)
Namibia	*Hippopotamus amphibius*	6	3	*Echinococcus felidis*	*nad1*, *cox1* and *pepck*, *pold*	Halajian et al. (2017)
	Panthera leo	6	4	*Echinococcus equinus*	*nad1*, *cox1*	Wassermann et al. (2015)
	Canis mesomelas	7	2			
	Equus quagga burchellii	12	11			
	Equus quagga			*Echinococcus ortleppi*	*nad1* and *cox1*	Obwaller et al. (2004)
	Oryx gazelle		8	*Echinococcus canadensis*	*nad1*	Addy et al. (2017)

(Mogoye et al., 2013). *Echinococcus granulosus* sensu stricto is widely distributed worldwide and is involved in most human cases (Romig et al., 2015) while reports on *E. canadensis* (G6) in Africa are confined in eastern (Wachira et al., 1993; Omer, 2004; Dinkel et al., 2004; Casulli et al., 2010; Mutwiri et al., 2013) and north African countries (Bart et al., 2004; Maillard et al., 2007) where camels are the main reservoirs for this genotype (Azab et al., 2004; Ibrahim et al., 2011). From the present review no conclusion can be made in relation to the contribution of animal species in the transmission of the reported *E. canadensis* (G6/G7) even if described as being primarily transmitted by camels and pigs respectively (Nakao et al., 2013b; Romig et al., 2017), however since camels are not found in Southern Africa, goats and cattle may be involved as they can also host the parasite (Addy et al., 2017). Although there is a considerable number of studies on *E. granulosus* complex in cattle in SADC countries with the majority of the infections being due to *E. ortleppi* (Romig et al., 2015) nothing can be said about the role of livestock in the transmission cycle of this complex due to lack of molecular studies in cattle and also in other livestock species. The sylvatic cycle of *E. equinus* in Namibia was established between lions (*Panthera leo*), Black-backed jackals (*Canis mesomelas*) and *Equus quagga burchellii* (Wassermann et al., 2015). In domestic cycle, this species is maintained by domestic canids and equines and its zoonotic potential has not been reported (Jenkins et al., 2005; Aboelhadid et al., 2013). *Echinococcus felidis* isolated from hippopotamus from the present review was already identified as of lion origin and the zoonotic potential is also unknown (Romig et al., 2015).

4.1. Gaps in knowledge and research priorities

The present review confirmed paucity of epidemiological information regarding echinococcosis in animals and humans in the SADC countries especially mass screening in humans. Based on the above, we assume that there may be a low investment by the national governments in both research and surveillance on echinococcosis probably due to several reasons such as i) the apparent healthy and asymptomatic cases or symptoms similar to other conditions with consequent application of investments in diseases causing high morbidity and mortality rates like HIV, tuberculosis and malaria ii) lack of records in both hospitals and abattoirs and iii) greater public health consideration of the disease in northern African countries than the SADC countries.

In order to fill the gaps in research and surveillance of the disease, we highlight the need to conduct prospective studies in order to update the existing data and to ascertain the true epidemiological situation and burden of this disease in humans and animals. We did not find any reports of echinococcosis or *Echinococcus* spp. from Malawi and Lesotho (member countries of SADC) and we do not believe that the parasite is not prevalent as they share borders between countries endemic to the disease with no restriction of movement of wild animals from one country to another.

Future epidemiological, molecular and serological based studies to determine the distribution, circulating genotypes of this parasite and trials of human vaccine candidates are required as a way of developing proper control measures especially in rural and poor pastoralist communities with poor health care systems and no provision of veterinary supervision during slaughter of animals and regular treatment of dogs. In human studies it is crucial to capture all the demographic information of patients such as locality, history of contact with animals and the health status of the patient as a way of determining the risk factors and provide better understanding of the epidemiology of the disease. Socioeconomic impact and disease burden estimation of human and livestock cystic hydatid disease are needed to convince and attract investments to concerted efforts to prevent and control the disease in the region.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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