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Review

Review of the Current Status on Livestock Abortigenic Diseases Surveillance in Africa and Asia

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Abstract: Introduction: Livestock abortigenic agents, which are microorganisms that lead to premature foetal death and expulsion before completion of the gestation period, are common in Africa and Asia. Abortion events cause economic losses by lowering reproduction (and hence herd/flock sizes) and effects on milk production. Despite the importance of livestock production for food security and livelihoods of millions of the world's poorest communities, very little is known about the scale, magnitude or causes of livestock abortion in Africa. The aim of this review was to determine the current status of the burden of livestock abortion and surveillance measures adopted for livestock abortigenic pathogens in Africa and Asia, and to explore feasible surveillance technologies. Methodology: A systematic literature search was conducted using Preferred Reporting of Systematic Reviews and Meta-analyses (PRISMA) guidelines in four databases for studies published between 1 Jan 1990 and 31 July 2021 that reported epidemiological surveys of livestock abortigenic pathogens in cattle, goats and sheep in Africa and Asia including; *Brucella spp., Neospora caninum, Toxoplasma gondii, Rift valley fever virus, Coxiella burnetii, Chlamydia, Leptospira and Bovine viral Diarrhoea Virus*. A meta-analysis was used to estimate the species-specific prevalence of the abortigenic diseases and the region where they were detected. Results: In the systematic literature search, 48 full papers were included which in total included 50 species-specific surveillance reports from Africa and 19 from Asia. Adjusted median seroprevalence calculations estimated *Brucella* at 6.85% (range 1.2-11.6) of 9071 sheep, 3.35% (range 0.90-5.40) of 17,007 goats, 8.95% (range 0.50-63.60) of 171,733 cattle, *Neospora* at 6.80% (range 6.80 -6.80) of 555 sheep, 10.80 (range 10.80-10.80) of 185 goats, 12.65% (range 3.40- 25.60) of 3775 cattle, *Toxoplasma* at 27.50% (range 1.40 – 75.90) of 2284 sheep, 32.0% (range 20.00- 64.80) of 1226 goats, 7.50% (range 7.50 - 7.50) of 174 cattle, *Coxiella* at 9.20 (range 9.20 – 9.20) of 184 sheep, 24.20% (range 24.20-24.20) of 91 goats, 13.80% (range 13.80-13.80) of 217 cattle, Rift valley fever virus at 7.70 (2.40-40.00) of 874 sheep, 20.95 (range 2.50-40.00) of 547 goats, 7.45% (range 3.60-11.30) of 309 cattle, Bovine viral diarrhea virus at 78.90 (range 78.90 – 78.90) of 398 cattle, Leptospira at 70.50 (range 70.50 – 70.50) of 373 cattle and Chlamydia at 6.60 (6.60-6.60) of 803 sheep. We found that most studies, 45 (89%) used serological surveys, 1 (2%) used molecular and 1 (2%) reported to have used Mobile-phone based surveillance approach. Three studies (6.25%) of the 48 included were embedded in the national surveillance programs of the respective countries they were conducted, majority 89% were stand-alone cross-sectional studies. Conclusion :In conclusion, livestock abortigenic pathogens are still a burden in many African and Asian countries.

Keywords: abortion; livestock; Africa; Asia

Introduction

Livestock abortion, as defined as foetal death and expulsion before completion of the pregnancy period in livestock, can be caused by microorganic abortigenic agents. These disease agents infect the reproductive organs of the animal resulting in the defective attachment of the foetus and thus its premature expulsion. Abortigenic agents in livestock include bacterial, protozoan, and viral agents [1]. Abortions may also be caused by other factors such as genetic disorders, trauma, environmental

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factors such as temperature, nutritional factors such as phytotoxins including mycotoxins as well as iatrogenic factors such as administration of abortigenic drugs [1]. However, infectious agents are the leading cause of abortion in livestock [2]. Common infectious agents that lead to abortion include *Neospora caninum*, *Brucella spp* and Rift valley Fever Virus in cattle, *Coxiella burnetii* in goats and sheep and pestiviruses in sheep [3–8]. In South Africa, abortigenic agents reported in resource poor farmers' cattle included *Brucella abortus*, *Neospora caninum*, BVD/MD virus, IBR/IPV, *Trichomonas fetus*, *Campylobacter fetus* [9].

The abortions in livestock are a major cause of economic losses to the farmers worldwide, making it an important phenomenon to monitor and control. The magnitude of the economic losses has been quantified in some parts of the world for specific pathogens. For example in South America the annual losses due to Neosporosis for the dairy industry were estimated to be $43.6 million USD (range, $15.62-194.41 million USD) in Argentina and $51.3 million (range, $35.8–111.3 million USD) in Brazil [10,11]

In addition to economic losses, some livestock abortigenic agents are zoonotic making them relevant to human health as well. Some of those infectious agents, including *Brucella abortus*, Rift valley fever, *Toxoplasma gondii* and Campylobacter among others, can cause fever and abortion in humans.

Developed countries have been successful in the control of some abortigenic agents by devising and implementing surveillance systems. These surveillance systems capture abortion events as quickly and accurately as possible. The implemented surveillance systems include the use of statutory testing as well as mandatory reporting by farmers of any abortion event to a veterinary inspector by phone who would then respond and act accordingly by testing and implementing appropriate interventions. (http://www.gov.scot/Topics/farmingrural/Agriculture/animal-welfare/Diseases/disease/Brucellosis/Surveillance). The surveillance platforms that have been successfully implemented in developed countries include passive, active, targeted, sentinel, syndromic, reportable disease, abattoirs and slaughter slab and emerging disease surveillance platforms [12]. These surveillance systems are implemented on a regular basis and for their successful implementation are coupled with well trained and equipped response personnel on the ground and state-of-the-art testing facilities[13].

However, it has been noted that one of the major constraints for control of abortigenic agents in low- and middle-income countries (LMICs) is the absence of qualitative and quantitative information. This is mainly due to lack of adequate implementation of surveillance systems for livestock diseases in most African and Asian countries. Currently available disease information is dependent on active disease search by researchers and includes limited or passive participation by the community. This has led to poor control of disease pathogens, including abortigenic agents, in LMICs, leading to unknown economic losses as well as no guidance for appropriate interventions. In East Africa as a region, there are ongoing research efforts to unravel the epidemiology of disease pathogens including abortigenic pathogens. Like in other LMICs, East African countries have a high burden of abortigenic agents [14–19], but few studies have attempted to estimate the economic losses due to of abortions. For instance, in Tanzania, the actual economic loss due to livestock abortions has not been determined due to lack of sufficient information for such kind of analysis. Currently, the surveillance data collected is not being sufficiently used in rapid response and priority setting in Tanzania[20]. This is mainly because the national surveillance system is not functioning optimally like in many other LMICs[20–22]. This has thus led to massive underreporting of abortion events in Tanzania, whereby approximately only less than 10% of all cases are reported (personal communication). The actual causes of the surveillance system not functioning optimally are also undocumented. Typically, the abortion surveillance system requires the abortion events to be reported to the government by the livestock keepers to the Livestock Field Officers (LFOs), stationed at village level. From there it is then reported to the District Veterinary officer (DVO) who reports to the Zonal Veterinary Centre Director (ZVC). The ZVC then informs the Director of Veterinary Services (DVS) at the Ministry Level. Regular reports of the number of abortion events are then provided to the global platforms at

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the World organization for Animal Health (OIE). The system is paper based from the LFO up to the ZVCs.

Despite the availability of established and successfully implemented surveillance systems in place in certain Northern countries, these may not be directly replicable in many African and Asian countries. Indeed, these systems may not be practical due their financial, infrastructural and expert requirements.

Using a systematic literature review process, we assessed the available literature on the studies that reported livestock abortigenic organisms in Africa and Asia including *Neospora caninum, Brucella spp.*, Rift valley Fever Virus, *Coxiella burnetii* and pestiviruses. Additionally, we determined the surveillance systems that are being used in Africa and Asia in reporting of livestock abortion events.

Methods

Study design and systematic review protocol

References were sought and identified following the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines[23] (Supplementary File 1 checklist). Studies were searched in PubMed, Scopus, Embase and google scholar published between 1 Jan 1990 and 31 July 2021. Search terms are listed in Table 1. The last search took place on 26 June 2021.

Table 1. Literature search strategies.

Search string	Database or further sources	Results	Date	Comments
((((ASIA[Text Word]) OR (AFRICA[Text Word]) AND (1990/1/1:2021/7/1[pdat])) AND (((GOATS[Title/Abstract]) OR (SHEEP[Title/Abstract])) OR (CATTLE[Title/Abstract]) AND (1990/1/1:2021/7/1[pdat]))) AND (ABORT*[Title/Abstract] AND (1990/1/1:2021/7/1[pdat]))) AND (surve*[Title/Abstract])	PubMed	29	2021-06-26	PubMed search
(TITLE-ABS-KEY (asia*) OR TITLE-ABS-KEY (africa*) AND TITLE-ABS-KEY (goats) OR TITLE-ABS-KEY (sheep) OR TITLE-ABS-KEY (cattle) AND TITLE-ABS-KEY (abort*) AND TITLE-ABS-KEY (surve*)) AND PUBYEAR > 1989	SCOPUS	64	2021-06-26	Scopus database through NM-AIST Library (AGORA)
((abort*:ti AND asia*:ti OR africa*:ti) AND goat:ab,ti OR sheep:ab,ti OR cattle:ab,ti) AND abort*:ti,ab,kw AND surve*:ti,ab,kw AND [1990-2021]/py	Embase	375	2021-06-26	Embase through NM-AIST
abortion surveillance cattle OR sheep OR goats * * * * "Asia OR Africa" -human -people -persons -man -woman -Europe -americas -australia -pacific -"south america"	Google Scholar	181	2021-06-26	Google Scholar search though NM-AIST

Search strategy

Article titles and abstracts were reviewed for suitability for inclusion by GS. They were selected for full text review if the studies investigated any of the abortigenic pathogens of interest, reported on samples collected from cattle, goats or sheep, involved surveillance of the abortigenic pathogens and data collection took place in African or Asian regions or countries as defined by the United Nations (UN) statistics division[24]. Full text articles were reviewed independently by two authors (GS, TK) to determine if each article met pre-determined inclusion and exclusion criteria (Supplementary File 2). Articles were included for full text review if the full text article could be retrieved, if it reported primary data, if the article reported surveillance data, in sheep, goats and sheep, regardless of laboratory methods used, if the prevalence of abortigenic pathogens could be calculated from information available in the paper from any sample type. Studies were excluded if the numerator (i.e. number positive) and denominator (i.e. number tested) information were not reported at the species and sample type level. Studies were excluded if they were focused on pathogens other than *Brucella spp., Neospora caninum, Toxoplasma gondii, Rift valley fever virus, Coxiella burnetii, Chlamydia, Leptospira and Bovine viral Diarrhoea Virus*. Studies were also excluded if they were in a language other than English. When required, a third author (KK) served as tiebreaker, independently reviewing articles to resolve disagreement between the two primary reviewers.

Article selection and data extraction

From each included article, we extracted information on species of the affected animal, sample type, the total number of samples tested, total positive samples. The number of pathogens detected was extracted to determine pathogen prevalence. Sample location data, including UN statistics division African and Asian geographic region countries[24]. A formal bias assessment was established (Supplementary Table S1), assigning low (L), moderate (M), high (H) to each potential introduction of bias. The bias elements considered in the formal assessment relating to abortigenic pathogens of interest, studies conducted out of Africa and Asia and technologies used. An overall assessment of low, moderate or high risk of bias was assigned to each included article.

Analysis

Prevalence estimates were calculated from pooled data for each pathogen by livestock species, geographic region and sample type. Summary statistics were also calculated in R.

Results

The literature search from the four scientific data bases resulted in 649 studies, which included abstracts, free full text, full text, books and documents, clinical trial and randomized controlled clinical trial including citations. After removing duplicate articles from the searches, 579 articles were available for title and abstract screening. Of these 89 (15.3%) were identified as potentially relevant and 48 (6.9%) were eligible for inclusion after full text review (Figure 1). Majority of the studies 25 (52.1%) were on Brucella spp., whereas Rift valley fever virus were 6 (12.5%) *Neospora caninum* 4(8.3%), and *Toxoplasma gondii* 5(10.4) of all the studies as summarized in Table 2 below. The number of studies from each country and the animal species investigated are listed in Table 3.

Three studies (6.25%) of the 48 included were embedded in the national surveillance programs of the respective countries they were conducted, majority 89% were stand-alone cross-sectional studies. Most studies, 31 (64.6%) were reported from Africa and 17 (35.4%) were done in Asia. Additionally, 41 (85.4%) of the studies included used serological surveillance and only 1 (2%) reported to have used Mobile-phone based surveillance approach while the others used bulk-milk survey, molecular survey, participatory epidemiology and active surveillance. This data is summarized in Supplementary File 3.

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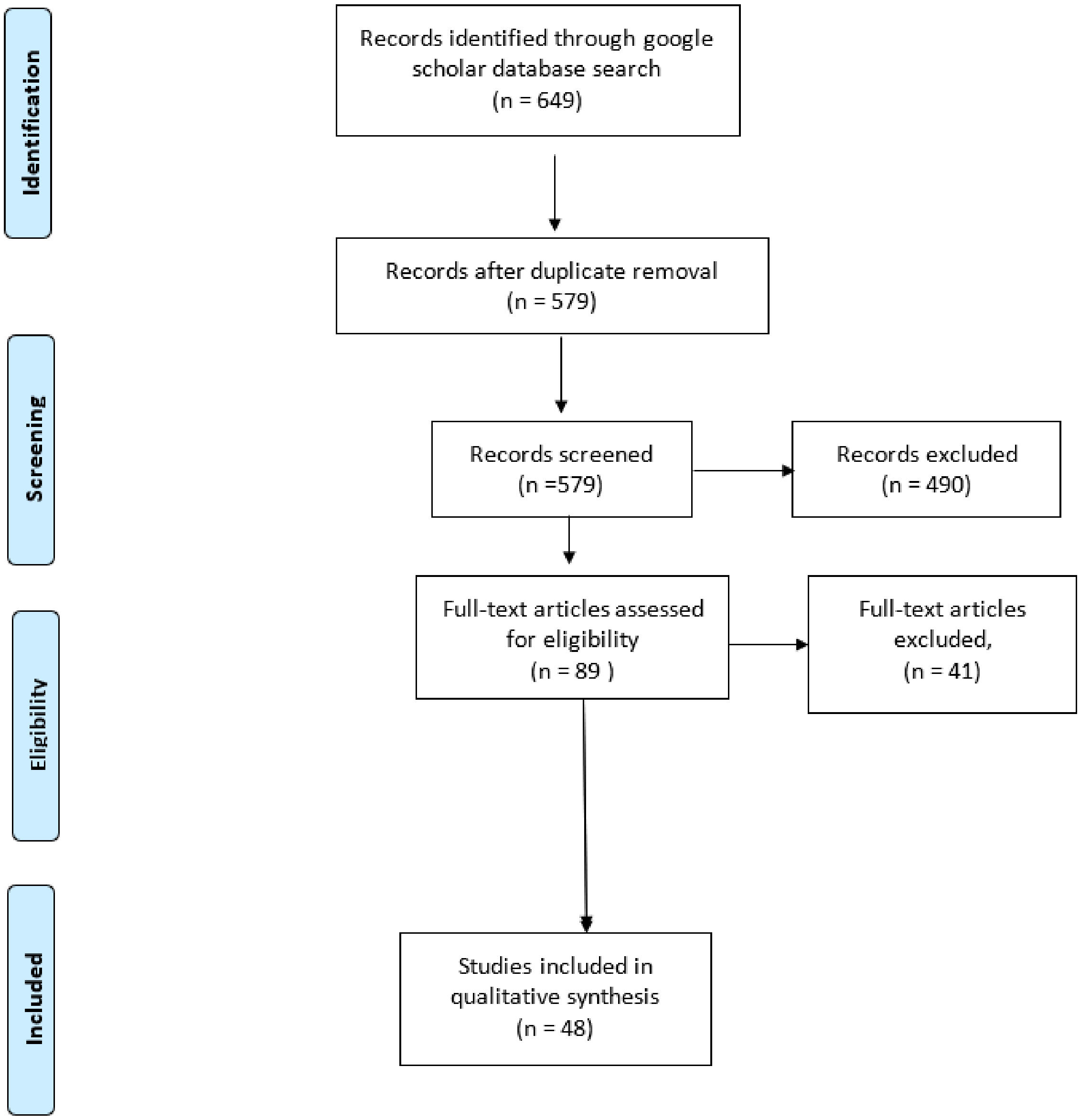

Figure 1. PRISMA Flow diagram showing identification, screening and selection of eligible articles for inclusion in Systematic review, 1990 - 2021.

Table 2. Numbers of articles on the livestock abortigenic pathogens and prevalences included in the systematic review by year of when sampling and testing began.

	Years				
Pathogen spp.	1990 - 1999	2000 – 2009	2010 – 2019	2020 - 2021	Total
Brucella spp.	2	4	16	3	25
Coxiella burnetii	0	0	1	0	1
Bluetongue virus	0	0	1	0	1
Chlamydia abortus	0	0	0	1	1
Leptospira spp	0	0	1	0	1

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Neospora caninum	0	1	3	0	4
RVFV	1	0	5	0	6
Toxoplasma gondii	0	1	1	0	5
BVDV, Brucella spp., N. caninum	0	0	0	0	1
Brucella spp., Coxiella burnetii, RVFV	0	0	1	0	1
N. caninum, T. gondii	0	0	1	0	1
T. gondii, N. caninum, Brucella spp.	0	0	1	0	1
Total					48

Median Prevalence of abortigenic pathogens

Adjusted median prevalence calculations estimated Brucella at 6.85% (range 1.2-11.6) of 9071 sheep, 3.35% (range 0.90-5.40) of 17,007 goats, 8.95% (range 0.50-63.60) of 171,733 cattle, Neospora at 6.80% (range 6.80 -6.80) of 555 sheep, 10.80 (range 10.80-10.80) of 185 goats, 12.65% (range 3.40-25.60) of 3775 cattle, Toxoplasma at 27.50% (range 1.40 – 75.90) of 2284 sheep, 32.0% (range 20.00-64.80) of 1226 goats, 7.50% (range 7.50 - 7.50) of 174 cattle, Coxiella at 9.20 (range 9.20 – 9.20) of 184 sheep, 24.20% (range 24.20-24.20) of 91 goats, 13.80% (range 13.80-13.80) of 217 cattle, Rift valley fever virus at 7.70 (2.40-40.00) of 874 sheep, 20.95 (range 2.50-40.00) of 547 goats, 7.45% (range 3.60-11.30) of 309 cattle, Bovine viral diarrhea virus at 78.90 (range 78.90 – 78.90) of 398 cattle, Leptospira at 70.50 (range 70.50 – 70.50) of 373 cattle and Chlamydia at 6.60 (6.60-6.60) of 803 sheep as summarized in Table 3 below. We found that most studies, 45 (89%) used serological surveys, 1 (2%) used molecular and 1 (2%) reported to have used Mobile-phone based surveillance approach.

Table 3. Seroprevalence of abortigenic pathogens by species.

Disease	Species	Cases (n)	Total tested (N)	Median Prevalence	Min	Max
Brucella	Sheep	981	9071	6.85	1.20	11.60
	Goats	887	17007	3.35	0.90	5.40
	Cattle	10662	171733	8.95	0.50	63.60
Neospora	Sheep	38	555	6.80	6.80	6.80
	Goats	20	185	10.80	10.80	10.80
	Cattle	367	3775	12.65	3.40	25.60
Toxoplasma	Sheep	595	2284	27.50	1.40	75.90
	Goats	493	1226	32.00	20.00	64.80
	Cattle	13	174	7.50	7.50	7.50
	Sheep	17	184	9.20	9.20	9.20

Coxiella	Goats	22	91	24.20	24.20	24.20
	Cattle	30	217	13.80	13.80	13.80
Rift Valley Fever Virus	Sheep	38	874	7.70	2.40	40.00
	Goats	37	547	20.95	2.50	40.00
	Cattle	19	309	7.45	3.60	11.30
BVD	Cattle	314	398	78.90	78.90	78.90
Leptospira	Cattle	263	373	70.50	70.50	70.50
Chlamydia	Sheep	53	803	6.60	6.60	6.60

Discussion

In this systematic literature search we found that livestock abortigenic pathogens are still are burden in the livestock sector in African and Asian countries. Furthermore, surveillance systems for livestock abortigenic pathogens in Africa and Asia are so far absent although the region has the highest rate of growth in surveillance systems using mHealth technology in human medicine. Additionally, most studies employed the serological surveillance approach in single timepoints using cross sectional study design. These studies demonstrated the burden of abortigenic pathogens but were not embedded in the national surveillance systems which would provide continuous real time information except for a few Asian countries; namely Japan and Fiji which had national Brucella surveillance programs.

Establishment of effective surveillance systems for zoonotic diseases has been on the research agenda for some time. This is because it is estimated that 75% of human epidemics and 60% of human pathogens are of animal origin [25]. These facts point out the importance of surveillance of zoonotic pathogens, among which, abortigenic agents belong. These abortigenic agents also cause economic losses in instances where they may not have caused disease to a human being.

Several different modes of surveillance have been proposed for zoonotic pathogens in different settings of the world with varying successes. For instance in France, it is mandatory for livestock keepers to report abortion events to the veterinary department by calling, failure to which a fine of 1500 euro is imposed [26]. However, even with advanced response systems in place in France, there are still many keepers that do not report abortions[26].

Participatory systems using mobile phone have been implemented for veterinary surveillance systems in several countries and across a range of diseases. For example, in Cambodia and Madagascar, participatory surveillance systems using mobile phone technologies have been successfully implemented for the surveillance of animal diseases in remote environments [27].

In Tanzania, like in most other African countries, mobile based technologies have been trialed in both human and veterinary medicine. Mobile phone technology has been applied successfully in zoonotic diseases like rabies in some parts of Tanzania [28]. Other veterinary programs whereby mhealth has been used include the innovative Smartphone App (AfyaData) for Innovative One Health Disease Surveillance from Community to National Levels in Africa [29]. This program has highlighted that rural areas have the potential to utilise mobile phone to link of livestock keepers with veterinary professionals and have timely access to information to assist in the diagnosis and treatment of livestock diseases. Furthermore, availability of mobile phones in rural areas, in combination with supporting infrastructure and facilities in urban areas, has potential to stimulate local development and improving delivery of animal health and extension service[30].

In human medicine, mhealth has been applied more extensively and has been more acceptable among health workers than in veterinary disease surveillance [31]. A number of programs are currently ongoing at the national level. These mhealth programs include maternal health and nutrition programs [32], in HIV/ AIDS [31], Malaria [33] and other diseases. Tanzania is reportedly setting the stage at the global level in integrating eHealth as a component of the national health system. Tanzania has established a community of practice working group since 2009 and in 2011 also developed a National mhealth strategy.

The documented major drawbacks of mobile based technologies include unclear benefits, uncertain long term results [32,34–38] and unknown cost-effectiveness [32,39]. Furthermore, there are still issues of under-reporting [36,37]. However, even with the drawbacks, mhealth is by far the most promising surveillance method especially for zoonotic diseases especially in Tanzania with the increasing mobile network coverage and mobile phone ownership in both rural and urban areas. Most of developing countries where feasibility studies for the application of mhealth and ehealth have been done have reported that most mhealth programs are done in silos without involvement of key stakeholders and hence unsustainability of the mhealth programs [40,41]

Conclusion

In conclusion, livestock abortigenic pathogens are a burden in many African and Asian countries. Surveillance systems for livestock abortigenic pathogens in African and many Asian countries are absent.

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