Retrospective study of anaplasmosis in countries of North Africa and the Middle East

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O. Parvizi (1), K.O. Akinyemi (2), U. Roesler (3), H. Neubauer (1) & K. Mertens-Scholz (1)*

(1) Friedrich-Loeffler-Institut, Federal Research Institute for Animal Health, Institute of Bacterial Infections and Zoonoses, Naumburger Straße 96a, 07743 Jena, Germany

(2) Department of Microbiology, Faculty of Science, Lagos State University, PO Box 0001, Lasu Post Office, Ojo, Lagos, Nigeria

(3) Institute for Animal Hygiene and Environmental Health, Free University Berlin, Robert-von-Ostertag Straße 7–13, 14163 Berlin, Germany

*Corresponding author: katja.mertens-scholz@fli.de

Summary

Anaplasmosis is a tick-borne disease caused by bacteria of the genus *Anaplasma*, which consists of six species affecting livestock and wild animals, and humans, worldwide. *Anaplasma marginale* and *Anaplasma phagocytophilum* are the most important species for veterinary and human health. Infections of livestock have a noticeable economic impact due to reduced growth or loss of animals. This study provides information on anaplasmosis in animal populations of countries in North Africa and the Middle East. Relevant national and international scientific publications were evaluated for studies of the epidemiology of anaplasmosis between 1959 and 2019. The serological assay results showed a prevalence of 13.5%–89.7% in cattle in North Africa, and 35%–36% in cattle, 44.7%–94% in small ruminants and 10.83% in camels in Middle Eastern countries. Sample positivity for *Anaplasma* species by molecular assays revealed a range of 3.5%–69.3% in cattle, 2.5%–95% in small ruminants and 17.7%–88.89% in camels in North African countries and 95% of cattle, 15.5%–66.7% of small ruminants and 28%–95.5% of camels in the Middle East. Polymerase chain reaction (PCR) detection of all six *Anaplasma* species in North Africa and of *Anaplasma ovis* and *A. phagocytophilum* in the Middle East was reported in livestock.

This review shows that anaplasmosis is endemic in North Africa and the Middle East and represents a threat not only to the economies of these countries but also to public health. Thus, surveillance and implementation of control measures are important tools to optimise future strategic control programmes and prevent spread to neighbouring countries.

Keywords

Anaplasmosis – Camel – Cattle – Goat – Middle East – North Africa – Prevalence – Sheep – Tick.

Introduction

Anaplasma spp. are fastidious, obligate intracellular, non-motile and gram-negative bacteria, belonging to the group of α proteobacteria within the order Rickettsiales (1). The genus consists of at least six species of veterinary or human health interest: *Anaplasma marginale*, *Anaplasma centrale* and *Anaplasma bovis* cause bovine anaplasmosis (BA), but pathogenicity differs among these species. *Anaplasma marginale* infects erythrocytes, and clinical signs intensify and the likelihood of death increases with age. Infected animals may become lifelong carriers (2). *Anaplasma centrale* and *A. bovis* are less pathogenic and cause mild disease in cattle (2, 3). *Anaplasma ovis* is the aetiological agent of ovine or caprine anaplasmosis. This is a mild disease of sheep and goats, but clinical signs can intensify depending on the host species and external stress factors (4). *Anaplasma platys* is responsible for canine infectious cyclic anaplasmosis (5). The only species with zoonotic potential is *Anaplasma phagocytophilum*, the aetiological agent of tick-borne fever in ruminants and of human granulocytic anaplasmosis (HGA) (6, 7). The main reservoirs are livestock, cats, dogs and wild animals. *Anaplasma phagocytophilum* is an emerging tick-borne disease and often causes a mild febrile illness with haematological abnormalities such as thrombocytopenia and leucopenia (8). Severe or fatal cases are rare (9, 10). There are reports of human infections involving *A. platys* and *A. ovis* (11, 12).

Anaplasmae are endemic in tropical and subtropical areas worldwide. They replicate within a parasitophorous vacuole, especially inside cells of the haematopoietic system (erythrocytes, platelets, monocytes, granulocytes), and clinical signs include anaemia, fever, weight loss, abortion and death. The infection cycle includes an invertebrate tick host, with transstadial but without known transovarial transmission (13). Ticks are ubiquitously present in the environment. Climate change together with an increasing number and movements of the vertebrate host and ticks, as well as their pathogenic cargo, may spread the pathogens and lead to outbreaks in countries regarded as free of anaplasmosis, as has been shown for other rickettsial diseases (14, 15). The key to reducing vector-borne diseases is control of the vector by improving awareness and surveillance, and establishing countermeasures as emphasised by the World Health Organization (WHO) (16). Besides ticks, Anaplasmae are transmitted mechanically by biting flies (17), iatrogenically via contaminated instruments (18) or via transplacental transmission in sheep and cattle (19, 20).

Available data from the literature imply that anaplasmosis is considered to be one of the major constraints to livestock management in endemic areas and poses a major challenge to smallholders facing reduced animal productivity, i.e. reduced weight gain, impaired spermatogenesis and abortions (21, 22, 23, 24). This leads to financial losses and negatively affects meat and milk production for the smallholder as well as for industry. The control of BA is costly and difficult and needs availability of diagnostic methods (7). The *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals* of the World Organisation for Animal Health (OIE) (25) recommends a competitive enzyme-linked immunosorbent assay (cELISA) for surveillance of

BA. This contributes to eradication and demonstrates population freedom from infection (with regular monitoring). Polymerase chain reaction (PCR) assays and microscopic examination are used for confirmation of clinical cases (25).

Countries of North Africa and the Middle East show a strong population and income growth; concurrently, the demand for agricultural goods is rising (26). For safe trading of animals and animal products, comprehensive epidemiological studies will be useful to clarify the course of anaplasmosis, considering current and future dispersion of the vertebrate host and tick vector. This will support the establishment of effective countermeasures for the future. This work presents a comprehensive overview of available information on anaplasmosis in countries of North Africa and the Middle East for evaluation of the current epidemiological situation.

Materials and methods

Availability of data and data analysis

Peer reviewed publications, articles and data from 1959 to 2019 were retrieved from relevant databases (PubMed, Google Scholar and Science Direct) using the search terms: prevalence, seroprevalence, anaplasmosis, diagnostic methods, risk factors and *Anaplasma* in combination with the respective country names of North Africa and the Middle East. Additionally, online Web-based resources, e.g. World Bank Group (WBG), World Integrated Trade Solution (WITS) and the Arab Organization for Agricultural Development (AOAD), were used to search for national and international publications. The countries involved in this study are: Algeria, Egypt, Libya, Morocco, Sudan, Tunisia and Western Sahara for North Africa, and Bahrain, Iraq, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, State of Palestine, Syria, United Arab Emirates and Yemen for the Middle East.

Legislation

The reliability and validity of extracted data were verified by applying the standard operating procedures (SOPs) of the OIE *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals* as an internationally recognised reference document (25). Criteria for eligibility were statements of the number of animals tested, history of anaplasmosis, sample collection method and type of sample, time and area of sampling and detection method used. The main critical point was the use of non-specific microscopic examination for epidemiological analysis. This technique is not approved by the OIE for diagnosis of anaplasmosis. However, non-specific techniques used for species-specific detection of *Anaplasma* in selected publications were corrected in order to use these data, as follows: studies that did not use species-specific methods but stated detection of a specific *Anaplasma* species were corrected to *Anaplasma* spp. These corrected studies are marked in Tables I to IV.

Results

A total of 46 publications were found that reported the detection of specific antibodies against *Anaplasma* spp. or the agent itself by microscopy or PCR in ruminant hosts such as cattle (n = 20), sheep (n = 4), sheep and goats (n = 7), camels (n = 8), zebu (n = 1), water buffaloes (n = 1) or other species (n = 5) (Tables I and II). These studies reported data from samples collected between 1990 and 2015. For non-ruminant hosts, the detection of *A. phagocytophilum* and *A. platys* was reported in 13 studies of client owned or stray dogs (n = 6), humans (n = 2), humans and dogs (n = 1), horses (n = 2), donkeys (n = 1) or foxes and lizards (n = 1) (Table III). Sample collection occurred between 1997 and 2016, or the period was not stated. Detection of *Anaplasma* spp. by PCR ranged from as low as 1.6% for dogs to 80% and 100% for foxes and lizards, respectively. Interestingly, one study reported a seroprevalence of *A. phagocytophilum* of nearly 70% for humans in Morocco. Screening of the tick vector was done in two studies also examining the vertebrate host and in ten tick-monitoring studies (Table IV).

No documentation or reports were found for Libya and Western Sahara in North Africa or for Bahrain, Lebanon, Syria, Oman, Kuwait and the United Arab Emirates in the Middle East. The distribution of reported *Anaplasma* species for countries of North Africa and the Middle East is summarised in Figure 1.

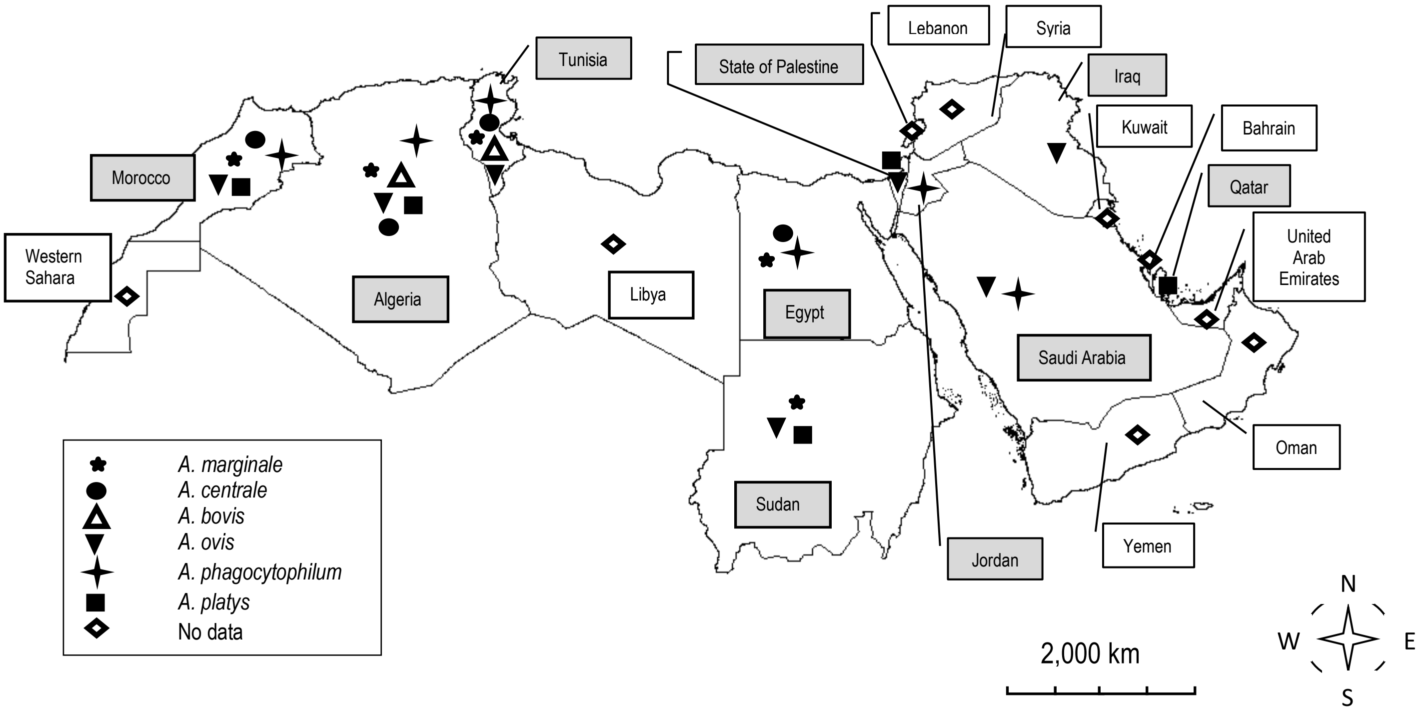

Fig. 1

Distribution of reported *Anaplasma* spp. in countries of North Africa and the Middle East

Countries with reports of *Anaplasma* spp. are displayed in grey boxes; countries with no reports are shown in white boxes

Table I

Summary of available information on detection of *Anaplasma* spp. in small and large ruminants in countries of North Africa

Country	Reference	Host	Number of animals tested	Prevalence (%)	*Anaplasma* spp.	Methods[f]			
						PCR[a]	IFA[b]	ELISA[c]	MC[d]
Algeria	(3)	Cattle	180	42.2%	*Anaplasma* spp.	x			
				39.4%	*A. centrale*				
				11.1%	*A. marginale*				
				4.4%	*A. bovis*				
	(27)	Cattle	36[e]	42%	*A. phagocytophilum*	x			
				12.8%	*A. platys*				
				13.9%	*Anaplasma* spp.				
	(28)	Cattle	138[e]	15.2%	*A. marginale*				x
	(29)	Sheep	120	61.7%	*A. ovis*	x			
		Goats	120	54.2%	*A. ovis*				
Egypt	(30)	Camels	331	15%	*A. marginale*	x			x
	(31)	Cattle	100[e]	26%	*A. marginale*	x			x
	(32)	Cattle	164[e]	20%	*A. marginale*	x			x
	(33)	Cattle	39[e]	100%	*A. marginale*	x			x
	(34)	Cattle	4,640	9.05%	*A. marginale*				x
	(35)	Cattle	3,310	3.7%	*A. marginale*		x		x
	(36)	Cattle	90	28%	*A. marginale*			x	
	(37)	Cattle	200	67%	*Anaplasma* spp.		~~x~~	x	x
		Buffaloes	160	78.1%					
	(38)	Cattle	40[e]	65%	*A. marginale*	x			x
	(39)	Water buffaloes	150	69.3%	*A. marginale*	x			
Morocco	(40)	Cattle	475	11.9%	*Anaplasma* spp.			x	
	(41)	Cattle	1,764	22.8%	*Anaplasma* spp.			x	
	(42)	Cattle	668	21.9%	*A. marginale*	x		x	
	(43)	Cattle	1,040	1.2%	*A. marginale*			x	
	(44)	Sheep/goats	422	71.8%	*Anaplasma* spp.				x
	(45)	Camels	106	39.62%	*Anaplasma* spp.	x			

Sudan	(46)	Cattle	805	57.6%	*A. marginale*			x	
	(47)	Cattle	243	~50%	*A. marginale*			x	
	(48)	Cattle	692	6.1%	*A. marginale*	x			
	(49)	Zebu	600	38.9%	*A. marginale*			x	
	(50)	Cattle	159	37.8%	*A. marginale*			x	
	(4)	Sheep	96	41.6%	*A. ovis*	x		x	
Tunisia	(51)	Camels	226	17.7%	*Anaplasma* spp.	x			
	(52)	Camels	226	29.2%	*A. phagocytophilum*		x		
	(53)	Cattle	232	34.9%	*Anaplasma* spp.	x			
				25.4%	*A. marginale*				
				15.1%	*A. centrale*				
				3.9%	*A. bovis*				
	(54, 55)	Goats	241	22.8%	*A. platys*-like	x			
				2.5%	*A. phagocyt.*-like				
		Sheep	335	11%	*A. platys*-like				
				3.9%	*A. phagocyt.*-like				
		Cattle	367	3.5%	*A. platys*-like				
				0.5%	*A. phagocyt.*-like				
	(56)	Sheep	972	30.7%–52.4%	*A. ovis*	x			
				0.1%–18.1%	*A. ovis/A. bovis*				
		Goats	7,139	21.7%–65.5%	*A. ovis*				
				2.2%–21.7%	*A. ovis/A. bovis*				
	(57, 58)	Goats	303	69.6%	*Anaplasma* spp.	x			
				65.3%	*A. ovis*				
		Sheep	260	23.8%	*A. bovis*				
				95%	*Anaplasma* spp.				
				93.8%	*A. ovis*				
				42.7%	*A. bovis*				
	(59)	Sheep	8,049	11.6%	*A. ovis*				x
	(60)	Cattle	328	24.7%	*A. marginale*	x			
				0.6%	*A. marginale/* *A. phagocytophilum*				

a PCR: polymerase chain reaction, includes PCR, nested PCR, real-time PCR and sequencing
b IFA: immunofluorescence assay
c ELISA: enzyme-linked immunosorbent assay, includes competitive ELISA
d MC: microscopy of blood smears
e Herds with a history of anaplasmosis and/or apparently ill animals
f Studies with several methods used are indicated by more than one cross, stated prevalence (%) data refer to PCR > IFA > ELISA > microscopy

Table II

Summary of available information on detection of *Anaplasma* spp. in small and large ruminants in countries of the Middle East

Country	Reference	Host	Number of animals tested	Prevalence (%)	*Anaplasma* spp.	Methods[e]			
						PCR[a]	IFA[b]	ELISA[c]	MC[d]
Iraq	(61)	Sheep	632	11.86%	*A. marginale*				x
				7.12%	*A. centrale*				
				0.63%	*A. ovis*				
	(62)	Sheep	500	4.8%	*Anaplasma* spp.				x
	(63)	Sheep	195	62.6%	*A. ovis*	x[f]			
	(64)	Cattle	100	35%	*Anaplasma* spp.			x	
	(65)	Camels	120	10.83%	*Anaplasma* spp.			x	
Jordan	(66)	Cattle	31	22%	*Anaplasma* spp.			x	
		Sheep	68	89%					
		Goats	36	82%					
Saudi Arabia	(67)	Camels	138	23.19%	*Anaplasma* spp.				x
	(68)	Camels	237	40.5%	*Anaplasma* spp.				x
	(69)	Sheep	548	2%	*A. ovis*				x
		Cattle	116	1%–3.4%	*A. marginale*				
	(70)	Cattle	307	0.98%	*A. marginale*				x
	(71)	Camels	44	95.5%	*Anaplasma* spp.	x			
		Cattle	20	95%					
		Sheep	50	100%					
	(72, 73)	Goats	123	24.4%	*A. ovis*	x	x	x	
				33.4%	*A. phagocytophilum*				
		Sheep	189	25.9%	*A. ovis*				
				39.2%	*A. phagocytophilum*				
	(74)	Camels	100	26%	*Anaplasma* spp.	x			
Palestine	(75)	Sheep	47	40.4%	*Anaplasma* spp.	x			
		Goats	1	0%	*Ehrlichia* spp.				

a PCR: polymerase chain reaction, includes PCR, nested PCR, real-time PCR and sequencing
b IFA: immunofluorescence assay
c ELISA: enzyme-linked immunosorbent assay, includes competitive ELISA
d MC: microscopy of blood smears
e Studies with several methods used are indicated by more than one cross, stated prevalence (%) data refer to PCR > IFA > ELISA > microscopy
f Reverse line blotting (RLB) was used for species identification

Table III

Detection of *Anaplasma* spp. in non-ruminant hosts in countries of North Africa and the Middle East

Country	Reference	Host	Number of animals or individuals tested	Prevalence (%)	*Anaplasma* spp.	Methods[d]		
						PCR[a]	IFA[b]	ELISA[c]
Algeria	(76)	Dogs	213	47.4%	*A. phagocytophilum*		x	
				14.6%	*A. platys*	x		
	(77)	Dogs	110	5.5%	*A. platys*	x		
Egypt	(78)	Humans	67	7.5%	*A. phagocytophilum*	x		
Morocco	(79)	Humans	10	70%	*A. phagocytophilum*		x	
		Dogs	425	7.5%	*A. platys*	x		x
	(80)	Humans	253	36.4%	*A. phagocytophilum*		x	
Sudan	(81)	Dogs	78	24.4%	*A. platys*	x		
	(82)	Donkeys	193	1.55%	*Anaplasma* spp.	x		
Tunisia	(83)	Horses	60	67%	*A. phagocytophilum*		x	
	(84)	Dogs	286	25.2%	*A. phagocytophilum*	x[e]	x	
	(85)	Horses	343	16.3%	*A. phagocytophilum*		x	
Jordan	(86)	Dogs	38	39.5%	*A. phagocytophilum*	x		
	(87)	Dogs	161	9.9%	*A. phagocytophilum*	x		
Qatar	(88)	Dogs	64	1.6%	*A. platys*	x		
Saudi Arabia	(71)	Foxes	5	80%	*Anaplasma* spp.	x		
		Lizards	10	100%				
Palestine	(75)	Dogs	135	11.1%	*Anaplasma* spp.	x		
		Horses	2	0%	*Ehrlichia* spp.			

a PCR: polymerase chain reaction, includes PCR, nested PCR, real-time PCR and sequencing
b IFA: immunofluorescence assay
c ELISA: enzyme-linked immunosorbent assay, includes competitive ELISA
d Studies with several methods used are indicated by more than one cross, stated prevalence (%) data refer to PCR > IFA > ELISA > microscopy
e Examined dogs included 58 apparently ill dogs

Table IV

Detection of *Anaplasma* spp. in arthropod vectors in countries of North Africa and the Middle East

Country	Reference	Vector	Number of arthropods tested	Number of positive vectors	*Anaplasma* spp.
Algeria	(29)	*R. bursa*	73	38	*Anaplasma* spp.
		R. turanicus	22	5	
Egypt	(39)	*Rhipicephalus*	280	433 (86.6%)	*A. marginale*
		Rhipicephalus (*Boophilus*)	150		
		H. a. excavatum (*H. a. anatolicum*)	30		
		H. a. excavatum	40		
	(89)	*R. sanguieneus*	413	13.7%	*A. phagocytophilum*
	(90)	*H. a. excavatum*	55	5	*Anaplasma*/
		Hyalomma Unident.	55	2	*Ehrlichia* spp.
		R. annulatus	625	27	
		R. sanguineus	49	1	
	(91)	*Xenopsylla cheopis*/*Hyalomma*	987	0	*A. marginale/A. platys*
		Rhipicephalus	1,019	3	
Morocco	(92)	*R. sanguineus*	125	19/167	*Anaplasma* spp./
		R. bursa	25		*Ehrlichia* spp.
		R. turanicus	3		
		I. ricinus	14		
	(93)	*I. ricinus*	221	13	*Anaplasma*-like
Tunisia	(93)	*I. ricinus*	197	19	*Anaplasma*-like
				2	*A. phagocytophilum*
		R. sanguineus	188	3	*A. platys*
		H. detrium	3232	1	*A. phagocytophilumlatys*
	(83)	*H. marginatum*	130	3	*A. phagocytophilum*
Palestine	(94)	*R. sanguineus/R. turanicus/ H. dromedarii/H. impeltatum/ Haemaphysalis parva*	200		*Anaplasma* spp. *A. ovis*
	(75)	*Hyalomma/Rhipicephalus/ Haemaphysalis*	723	1.8%	*A. platys*
				2.5%	*A. ovis*
				2.2%	*Anaplasma* spp.

H.: *Hyalomma*
H. a.: *Hyalomma anatolicum*
I.: *Ixodes*
R.: *Rhipicephalus*
Unident.: Unidentified

Countries of North Africa

Algeria

Reports of detection of *Anaplasma* spp. in ruminants, dogs and ticks have been published since 2015 and have included areas of Batna, Béjaïa, Setif, El Eulma, Anaba, El Tarf, Tizi Ouzou and Souk Ahras. Three scientific reports were available for detection of *Anaplasma* spp. in cattle (3, 27, 28), of which two examined apparently ill animals (27, 28). Prevalence by PCR detection ranged from 15% to 40% (Table I). One study examined sheep and goats and revealed that over 50% of animals tested positive for *A. ovis* by PCR. In addition, the authors collected *Rhipicephalus bursa* and *R. turanicus* ticks, which were also positive for *Anaplasma* spp. (Table IV) (29). Other studies reported the detection of *A. phagocytophilum* and *A. platys* by PCR and immunofluorescence assay (IFA) in dogs, with up to 47.7% positivity (Table III) (76, 77). The collected data imply that anaplasmosis is present with a locally high prevalence in Algeria.

Egypt

Bovine anaplasmosis in Egypt is first mentioned in the national report of 1966 which was retrieved by the Central Agency for Public Mobilization and Statistics (CAPMAS), Egypt (95). Since then, in some parts of the country, i.e. Matrouh, Damitta, Dakahlia, Qalyubia and Qena, detection of mainly *A. marginale* or *Anaplasma*-specific antibodies has been reported. From 15 publications, seven reports are on cattle, one on water buffaloes, one on water buffaloes and cattle, one on water buffaloes and ticks, one on camels, three on arthropods and one on humans (Tables I to IV). Of all eight studies in cattle, four investigated obviously ill animals or animals with a history of anaplasmosis by PCR as well as microscopy. The prevalence was accordingly high, at up to 100% (30, 31, 32, 33). Two authors reported on screening by microscopy and confirmation by PCR of the detection of *A. marginale* in cattle, with 55% and 3.7% positivity, respectively (34, 35). Other authors reported seropositivity for anaplasmosis at 28% (36), 67% (37) and 65% (38) in cattle, and 69.3% in water buffaloes and 86.6% in ticks (39), respectively. A survey of farmers in the Nile Delta revealed that 7.5% were positive for *A. phagocytophilum* by PCR (78). Comprehensive studies of *Anaplasma* spp. were carried out on ticks and fleas in 2012 or 2006, respectively (89, 90, 91, 96) with a surprisingly low detection rate by PCR (Table IV). These data imply that monitoring by microscopy at the government level might be a good tool for screening large groups of animals but always needs the addition of confirmatory serological and molecular detection methods.

Morocco

The first report of BA in Morocco, with a seroprevalence of 11.9%, was published in 1998 (40). Three studies examining cattle from central and northern regions showed higher seroprevalences of approximately 20% (Table I) (41, 42, 43). *Anaplasma marginale* was confirmed in one of these studies by PCR (42). Camels from southern areas and small ruminants from northern parts were positive at 39.6% by PCR and 71.8% by microscopy, respectively (44, 45). Human infections due to *A. phagocytophilum* were demonstrated by IFA. Associated pet or non-pet dogs were positive for *A. platys* by PCR and enzyme-linked immunosorbent assay (ELISA) (79, 80). The prevalence of *Anaplasma* spp. in the tick host was 5% to 11% (Table IV) (92, 93). Taken together, the reports summarised here cover the northern, central and southern parts of Morocco and imply an overall prevalence of *Anaplasma* spp.

Sudan

Domestic animals play an important role in the Sudanese economy (97) and four publications focusing on cattle, one on zebu, one on sheep and two on non-ruminant hosts (dogs and donkeys) were published between 2006 and 2012 (Table I). The most commonly used technique was cELISA, revealing a prevalence of 37.8%–57.6% in bovines, including zebu (46, 47, 48, 49, 50). These studies cover northern, central and southern areas of Sudan. *Anaplasma ovis* was reported once (4). In non-ruminant hosts, a high prevalence of *A. platys* (24.4% by PCR) in stray dogs and a low prevalence of anaplasmosis in working donkeys (1.6% by microscopy) were observed (Table III) (81, 82).

Tunisia

In Tunisia, the detection of five *Anaplasma* species by various PCR methods was reported in 14 scientific articles: *A. phagocytophilum* in ticks (93), camels (51, 52) and horses (83, 85), *A. platys* in ticks (93) and dogs (84), *A. bovis* in cattle (53, 54, 55), *A. ovis* and *A. bovis* in sheep and goats (56, 57, 58, 59), and *A. marginale*, *A. bovis* and *A. centrale* in cattle (53, 60). For cattle (53) and camels (52), the reported detection rates by PCR are up to 35% or 30%, respectively (Table I). In small ruminants, a much higher detection rate was published, with a maximum of 95% in sheep and 69.6% in goats (57, 58). Additionally, Belkahia *et al.* demonstrated seasonal variations for *A. ovis* and *A. bovis* in small ruminants, with a minimum in spring and a maximum in autumn (56). In non-ruminant hosts, *A. platys* was detected in 24.4% of dogs (by PCR) (84) and *A. phagocytophilum* in 67% of horses (by IFA) (83), emphasising the zoonotic potential of the latter (Table III). The presence of *A. phagocytophilum* in *Hyalomma detritum* collected from cattle and *Ixodes ricinus* collected from the environment, as well as *A. platys* in *Rhipicephalus sanguineus* collected from dogs, was proven (93) (Table IV). Although loop-mediated isothermal amplification (LAMP) and restriction fragment length polymorphism (RFLP) techniques are not recommended by the OIE, these methods may benefit diagnostics in developing countries.

Countries of the Middle East

Iraq

Anaplasma ovis was first mentioned by Khayyat & Gilder in 1947 (98). Six available publications cover the regions of Al-Najaf, Babylon, Baghdad, Baquba, Duhok, Erbil, Sulaimaniya and Wasit. Most publications focus on ovine anaplasmosis (Table II). Non-specific methods such as microscopy were used in two studies and revealed a seroprevalence of 19.61% (61) or 4.8% (62), respectively. One study, carried out in Sulaimaniya, used reverse-line blotting and detected *A. ovis* in 62.6% of animals examined (63). Cattle (64) and camels (65) were shown to be positive by ELISA, at 35% and 10.83%. However, the bovine ELISA kit 'indirect ELISA *A. marginale*-Ab (Svanova Biotech AB, Uppsala, Sweden)' was used on camels without validation. Interestingly, several DNA sequences have been deposited by the Iraqi universities of Baghdad Al-Qadisiyah and Al-Qasim at the National Center for Biotechnology Information (NCBI, https://www.ncbi.nlm.nih.gov/) for *A. phagocytophilum*, *A. marginale*, *A. ovis* and *A. centrale*. It would be of great benefit to gain knowledge about the epidemiological aspects of these *Anaplasma* spp.

Jordan

One cross-sectional study is available examining ruminant hosts for anaplasmosis by ELISA (Table II). The seroprevalence at farm level was estimated at 36%, 94% and 94% for cow, sheep and goat farms as well as at animal level, with 22% for cattle, 89% for sheep and 82% for goats (66). Detection of *A. phagocytophilum* in non-ruminant hosts varies: carcasses of stray dogs showed 39.5% *A. phagocytophilum* positive samples when examined by species-specific PCR (86) but 9.9% of dogs (pet, stray, working) were found to be seropositive in different areas of Jordan such as Amman, Jarash, Irbid, Ajloun and the Northern Jordan Valley (Table III) (87).

Qatar

Pet animals, cats and dogs, were screened by conventional PCR for vector-borne diseases (Table III). Among the dogs, 1.6% were infected with *A. platys*, whereas all cats examined were negative (88).

Saudi Arabia

The most commonly used diagnostic method was microscopy (four of eight studies), and camels were positive for anaplasmosis at 40.5% or 23.19% (67, 68), sheep at 2% and cattle at 1%–3.4% (69, 70). Ghafar

& Shobrak examined cattle, camels, sheep, foxes and spiny-tailed dabb lizards by PCR and sequencing. In none of these animals could the *Anaplasma* species be identified (Table II) (71). Another study used PCR and sequencing for identification and revealed that 26% of camels examined were positive for *Anaplasma* spp. (74). Shabana *et al.* showed that 47.4% and 54.4% of samples from small ruminants were positive using cELISA and IFA, respectively (72). Molecular investigations of small ruminants revealed the prevalence of *A. ovis* and *A. phagocytophilum* to be up to 25% or up to 40%, respectively (73).

State of Palestine

A pilot study in 2015 was performed using the 16S rDNA as the target for PCR-based screening of 723 tick samples of genera *Rhipicephalus*, *Haemaphysalis* and *Hyalomma* from the West Bank. This study revealed that 6.5% (47/723) of ticks were positive for *Anaplasma* spp., 2.48% for *A. ovis* and 1.79% for *A. platys* (Table IV) (94). In addition, 40.4% (19/47) and 9.62% (13/135) of blood samples from sheep and dogs were positive for *Anaplasma* spp. and *A. platys*, respectively (Table III) (75).

Yemen

One accessible investigation was retrieved from 1987 in the areas of Al Hamilee, Hyma Sufla and Misgab as Seloo. The authors used a non-specified serological method, and all cattle analysed were negative (99).

Discussion

Animal populations in countries of North Africa and the Middle East are steadily increasing (AOAD, http://www.aoad.org/eaasyxx.htm). Animal production contributes significantly to the national economies and the social welfare of smallholders' families (97). Bovine anaplasmosis presents a high burden, and physical losses from animal death, weight loss, chronic cases (culling of the animal) and abortions (loss of progeny) directly translate to financial costs and expenses from veterinary attention, administered drugs, additional labour and management. These costs amounted to $8,964,293 for Texas in 1980. Additionally, BA leads to national and international trading restrictions. It was shown that infection of cattle with *A. marginale* can lead to a 3.6% reduction in successful calving and it increases the animal culling rate as well as the mortality of animals with clinical signs by 30% (100). Similar infections of small ruminants with *A. ovis* can lead in some cases to high losses (reduced milk production, reduced progeny, abortions), and the zoonotic potential of this species remains to be re-evaluated (4). Facing these costs, surveillance and control measures are needed to control BA and would benefit the control of other vector-borne diseases (21).

Analysis of available prevalence data from 1959 to 2019 show that comprehensive surveillance studies for domestic and wild animals are not available for North Africa and the Middle East. For Egypt, extensive studies exist describing the presence of *Anaplasma* spp. in ticks. Reports were available from 19 countries, excepting Libya, Western Sahara, Bahrain, Kuwait, Lebanon, Oman, Syria and the United Arab Emirates. Many studies on surveillance were done in cooperation with OIE/WHO reference laboratories, national laboratories or universities in France, Italy, Germany, Japan, the United Kingdom and the United States of America (USA), etc. The most frequently used diagnostics are DNA amplification methods, ELISA and IFA. The accessible commercial serological kits used in publications are: '*Anaplasma* antibody competitive ELISA v2 (VMRD Inc., Pullman, Washington, USA)', 'SNAP® 4Dx® Plus Test (IDEXX, Hoofddorp, the Netherlands)', '*Anaplasma* immunoglobulin G ELISA (IgG): a semi-quantitative indirect IFA (Fuller Laboratories, Fullerton, California, USA)', 'indirect ELISA *A. marginale*-Ab (Svanova Biotech AB, Uppsala, Sweden)' and '*A. phagocytophilum* indirect immunofluorescence test kit (Fuller Laboratories, Fullerton)'. The use of a bovine ELISA kit, 'indirect ELISA *A. marginale*-Ab (Svanova Biotech AB, Uppsala)', on camels (65) was done without validation, which may have affected the cut-off value.

In ten countries, laboratories tried to differentiate *Anaplasma* spp., while there were no data on particular *Anaplasma* spp. in nine countries (Fig. 1). No attempts to isolate the microorganisms in cell culture were published in any of the countries in this region. The presence of almost all economically relevant species of the genus *Anaplasma* (*A. marginale*, *A. centrale*, *A. bovis*, *A. ovis*, *A. platys* and *A. phagocytophilum*) was confirmed by species-specific PCR. *Anaplasma marginale* is highly prevalent in cattle (25.4%, Tunisia), camels (15%, Egypt) and water buffaloes (69.3%, Egypt), all economically important ruminants. Similarly, the prevalence of *A. ovis* is high, at 65.3% and 93.8% in goats and sheep from Tunisia. Without the implementation of countermeasures and surveillance, this will lead to further spread and higher costs for the owner. *Anaplasma phagocytophilum* and *A. platys* have been identified using molecular techniques on samples from Iraq, Jordan and Saudi Arabia. Both species can infect humans. *Anaplasma phagocytophilum* causes similar economic losses to *A. marginale* in the cattle industry and sheep and goat farming but has zoonotic potential and causes mild to severe infections in humans. In countries in the south of the Persian Gulf, *A. phagocytophilum* was demonstrated in pets (101). The number of samples positive for *Anaplasma* spp. in farm animals using serological and molecular assays differed from one country to another within this region. This observation may be attributed to different methods of identification and investigation, and to the degree of political stability within the region. In addition, in Saudi Arabia, a high number of *Anaplasma* spp. positive samples were observed in slaughtered sheep and goats (73). Furthermore, in Morocco, 22% of samples from blood donors tested positive using IFA (80). This observation is of great interest and such mechanisms of transfer aid the zoonotic transmission of anaplasmosis and possible spread to other neighbouring countries.

Conclusion

This review showed that anaplasmosis is endemic in countries of North Africa and the Middle East. It bears the potential for further spread, especially considering the adverse climatic conditions in this region. Thus, surveillance and implementation of control measures are needed. International support will help to implement control and monitoring measures during animal transportation. However, further research is required on the epidemiology of anaplasmosis in the countries of the Middle East and North Africa to prevent the spread of infection to neighbouring countries.

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