A review on camel brucellosis: a zoonosis sustained by ignorance and indifference

Lisa D. Sprague¹, Sascha Al-Dahouk², Heinrich Neubauer¹

¹Friedrich-Loeffler-Institut, Jena, Germany, ²Bundesinstitut für Risikobewertung, Berlin, Germany

In many developing countries of Asia and Africa, camels are one of the most important sources of income for the nomadic population. With increasing urbanization, camel milk and meat have gained a wider market and commercialization and consumption of camel products are on the rise. Camel brucellosis can be encountered in all camel rearing countries with exception of Australia. High animal and herd prevalences have been reported from numerous countries, which not only pose a continuous risk for human infection, but also increase the spread of infection through uncontrolled trade of clinically inconspicuous animals. This short review aims at providing an overview on diagnostic investigations, as well as the public health and economic impact of brucellosis in old world camels.

Keywords: Brucellosis, Camel, Milk, Meat, Public health

Introduction

Old world camels are even-toed ungulates belonging to the genus *camelus* which distinguishes two species: the two-humped Bactrian camel (*Camelus bactrianus*) and the one-humped Arabian camel (*Camelus dromedarius*), also known as dromedary (henceforth referred to as 'camel').¹ The former is native to the arid regions of central and East Asia, the latter to the desert areas of western Asia, North Africa, and the near and middle East.² In many developing countries of Asia and Africa, camels are the most important source of income for the nomadic population.³ Both species are not only kept as working animals, but also as providers of milk, meat, wool, leather and fuel. With increasing urbanization, camel milk, a major component of the diet in many pastoralist societies, has gained a wider market and commercialization and consumption of camel milk is on the rise.⁴ Camels are moreover a good source of low-cost meat as they provide reasonably heavy carcasses under inexpensive husbandry systems.⁵ Camel meat is mainly consumed in countries surrounding the Red Sea, such as Saudi Arabia and Jordan.⁶

The Food and Agriculture Organisation of the United Nations (FAO) estimated in 2009, that the world population of camels (excluding Australia) encompassed approx. 26 million animals, with a gross production value of 342 million US\$ for milk and of 1000 million US\$ for meat.⁷ These figures are probably going to increase, since camels will most

likely replace those livestock not capable of adapting to the environmental transformations arising from the imminent climate changes. Camels are also an important part of local tradition and contribute to the local economy not only as a tourist attraction, but also as valuable racing animals. Camel racing is very popular in the countries of the Arabian Gulf and North Africa and accompanied by active camel trading.⁸

Although camels are hardy and undemanding in their maintenance, they are not resistant to diseases affecting other livestock, as frequently assumed in the past. Camels are generally raised under very harsh and stressful conditions with regard to temperature, water availability, and nourishment and thus they are prone to develop serious health problems.⁹ In fact, numerous studies revealed that camels are highly susceptible to certain bacterial pathogens such as *Bacillus anthracis*, *Mycobacterium* spp, *Clostridium* spp, *Pasteurella* spp, *Salmonella* spp, and *Brucella* spp.³ Brucellosis in camels is an insidious disease, since it hardly provokes any clinical signs,¹⁰ and may furthermore cause problems in the laboratory due to the lack of sufficiently validated tests. While brucellosis is most likely one of the oldest recognized diseases of mankind and under control in most developed countries, the containment of this zoonosis has been ignored elsewhere as it mostly affects the poor. This attitude is short sighted since the resulting medical, veterinary, and socioeconomic problems are (un)foreseeable.¹¹ This short review aims at providing an overview on diagnostic investigations, as well as

Correspondence to: L. D. Sprague, Friedrich-Loeffler-Institut, Jena, Germany. Email: natter13@gmx.de

the public health and economic impact of brucellosis in camels.

Aetiology and Clinical Findings

Brucellae are Gram-negative, amotile, facultative intracellular coccobacilli or rods; the genus presently consists of 10 classified and 3 unclassified potential species, of which seven are pathogenic for humans (Table 1). The currently described *Brucella* species all belong to a single species, as DNA homology data have shown. However, the historic species definition was based primarily on host preference and phenotypic characteristics, i.e. oxidative metabolism and phage lysis tests. Currently, this system is critically discussed. A species is described by the following parameters: colony morphology, agglutination with anti-S sera, lysis by different phages, oxidase and urease activity, and host preference. Within the species, the biovars are defined by their requirement of CO₂, H₂S production, growth on dyes (thionin, basic fuchsin) and the agglutination with the mono-specific sera A, M, and R. Recent approaches include genomic information e.g. *OMP2* sequence, 16S rRNA gene sequences, and grouping systems based

on MLST profiles.¹² Camels are infected by various biovars of the two species *B. abortus* and *B. melitensis* (Table 2).

Brucella spp. can enter the body through the lungs, the digestive tract, mucous membranes, and intact skin. Once in the blood stream, the organism disseminates to multiple organs, thereby displaying an affinity for reticuloendothelial tissues, such as liver, spleen, the skeletal, and hematopoietic system.¹³

The clinical picture of brucellosis in camels can vary from asymptomatic to abortion.¹⁴ Dams can develop ovario-bursal adhesions, hydrobursitis, and granulomatous endometritis. Placental retention, infertility, and delayed sexual maturity have also been reported.¹⁰ Males may suffer from orchitis.³ Musa *et al.*¹⁴ reported the occurrence of arthritis accompanied by acute lameness.

Although asymptomatic infections regularly occur in humans, this multisystemic disease frequently presents with a wide range of symptoms. It usually begins as an acute febrile disease with non specific flu-like symptoms, such as fever, headache, malaise, back pain, myalgia, drenching night sweats, and generalized ache. Undulant fever may develop which can last up to

Table 1 Currently described *Brucella* species and their zoonotic potential

Species	Biovars	Animal host	Human disease	First description (see Ref. 52)
<i>Brucella</i> (<i>B.</i>) <i>abortus</i>	1–9	Cattle, bison, buffalo, elk, yak, camel	Yes	Schmidt, 1901; Meyer and Shaw, 1920
<i>B. melitensis</i>	1–3	Sheep, goat, cow, camel	Yes	Hughes, 1893; Meyer and Shaw, 1920
	3	Nile catfish; dog		53; 54
<i>B. suis</i>	1	Horse	Yes (biovars 1–4)	Cook and Kingston, 1988
	1, 2, 3	Pig, wild boar		Huddleson, 1929
	2	European hare		
	4 (<i>B. rangiferi</i>)	Caribou, reindeer		
	5	Rodents	Yes	
<i>B. ovis</i>		Ram	Not reported	Buddle, 1956
<i>B. neotomae</i>		Rodent	Not reported	Stoenner and Lackman, 1957
<i>B. canis</i>		Canines	Yes (rarely)	Carmichael and Bruner, 1968
<i>B. ceti</i>		Whale, dolphin, porpoise	Yes	Foster <i>et al.</i> , 2007
<i>B. pinnipedialis</i>		Seal	Not reported	Foster <i>et al.</i> , 2007
<i>B. microti</i>		Common vole, red fox; (soil)	Not reported	Scholz <i>et al.</i> , 2008
<i>B. inopinata</i>		Human	Yes	Scholz <i>et al.</i> , 2010
<i>Baboon isolate</i>		Baboon	Not reported	Schlabritz-Loutsevitch <i>et al.</i> , 2009
<i>BO2</i>		Unknown	Yes	Tiller <i>et al.</i> , 2010
<i>Australian rodent strains</i>		Rodent	Unknown	Tiller <i>et al.</i> , 2010

Table 2 *Brucella* species isolated from old world camels

Country	Species	Biovar	Method	Reference
Mongolia, Russia, Azerbaijan	<i>B. melitensis</i>	2	PCR, MLVA	55
Sudan	<i>B. abortus</i>	6	b.e.	56
	<i>B. melitensis</i>	3		14
	<i>B. abortus</i>	6		
	<i>B. abortus</i>	3		9
Jordan	<i>B. melitensis</i>	3	b.e.	28, 57
Egypt	<i>B. melitensis</i>	3	b.e.	64
	<i>B. abortus</i>	1, 7		58, 59, 60
Saudi Arabia	<i>B. melitensis</i>	1, 2, 3	b.e.	21, 22, 61, 62
	<i>B. abortus</i>	n.d.		63
Libya	<i>B. melitensis</i>	1	b.e.	20
Kuwait	<i>B. abortus</i>	1	b.e.	64
Iran	<i>B. melitensis</i>	1, 3	b.e.	65, 66

Note: MLVA: multiple-locus variable number of tandem repeats analysis; b.e.: bacteriological examination; n.d.: not determined.

12 months. Neurological signs can occur in up to 5% of cases. Fatalities can be observed due to the development of endocarditis. Since many organs and tissues can be affected, a multitude of syndromes can result such as nephritis, dermatitis, vasculitis, lymphadenopathy, deep vein thrombosis, granulomatous hepatitis, osteomyelitis, and formation of abscesses in internal organs. Congenital brucellosis can lead to preterm birth, with signs of septicaemia, but asymptomatic or cases with mild symptoms have also been reported. Whether brucellosis can lead to spontaneous abortion in humans is still a matter of debate (www.cfsph.iastate.edu/Factsheets/pdfs/brucellosis.pdf).¹⁵

Diagnostic Investigations

Recent data on the prevalence of brucellosis in camels are relatively scarce, albeit several reviews have painstakingly summarized the numerous reports found in the literature.^{3,16–18} Most of the reports address the seroprevalence of brucellosis in camels; this is not surprising due to the relative ease by which samples can be obtained and handled. Diagnosing brucellosis by means of cultivation and phenotypic characterization is not only laborious and time consuming; it also poses a major risk of infection for the investigator. Successful isolation or demonstration of the agent has been achieved by sampling lymphoid tissue,¹⁹ aborted foetuses, vaginal swabs,²⁰ milk,^{21,22} testes,²³ and infected joints.¹⁴

Results gained from serological surveys and the conclusions drawn should, however, be regarded with caution, since the tests applied have been validated for their use in cattle only. The classical serological tests for detecting antibodies against *Brucella* spp. are the complement fixation test (CFT), the Rose Bengal test (RBT), and the serum agglutination test (SAT). All three tests have their limitations regarding sensitivity, i.e. correct identification of truly positive animals, and are not appropriate for screening individual animals.²⁴ The CFT for example, is a

mandatory test for international trade as required by the World Organisation for Animal Health (OIE), but it has severe drawbacks: it is complex, time consuming and difficult to standardize.²⁵ The RBT, on the other hand, can only be applied to the monitoring of flocks in *Brucella* free regions. The SAT is less specific than the CFT, but has been used in surveillance and control programmes for bovine brucellosis (OIE). Finally, it must be kept in mind that the serodiagnosis of Brucellosis is additionally impaired by the allegedly strong cross-reactivity between *Brucella* spp and *Yersinia enterocolitica* O:9 and other Gram-negative bacteria.²⁶

In a recent study, Gwida *et al.*²⁷ compared various serological tests, i.e. RBT, SAT, CFT, cELISA, and the fluorescence polarization assay (FPA) on 895 sera from clinically healthy camels. Best results for detecting the presence of anti *Brucella* antibodies were obtained by the FPA (79.3%), followed in descending order by the CFT (71.4%), RBT (70.7%), SAT (70.6%), and cELISA (68.8%). Only 66.5% of the samples were positive in all serological tests. In addition, this study also assessed the usefulness of a real-time PCR, targeting the genus specific *Brucella* cell surface salt extractable *bcs31* kDa protein gene, which was detectable in 84.8% of the samples. The authors therefore recommended the use of the FPA in combination with the real time PCR in developed countries, or conventional PCR with any of the commonly used serological tests in less developed countries.

Epidemiology and Public Health

Camel brucellosis caused by *B. abortus* or *B. melitensis* biovars can be encountered in all camel rearing countries with the exception of Australia. High animal and herd prevalences have been reported from numerous countries, which not only pose a continuous risk for human infection (Table 3), but also increase the spread of infection through uncontrolled trade of clinically inconspicuous animals.

Table 3 Seroprevalence of camel brucellosis in some North and sub-Saharan African countries*

Country	No. of samples	Test	Prevalence (%)	Reference
Sudan	2000	RBPT	39.9	56
		cELISA	40.5	
Sudan	21		23.8	
	62	RBPT/SAT	9.67/8.06	14
Libya	14	RBPT	14	34
Egypt	unknown	unknown	7	16
Somalia	1246	RBPT	3.9	
		iELISA	3.1	29
Chad	288	RBPT	0.4	33
Ethiopia	1073	RBPT	2.1	
		CFT (confirmatory)	1.8	30
Ethiopia	1442	RBPT	5.7	
		CFT	4.2	67

Note: *No data were obtainable from central Asia and China (with the exception of Mongolia).

RBPT: Rose Bengal plate test; CFT: complement fixation test; iELISA: indirect ELISA; SAT: serum agglutination test.

Several risk factors have been identified for camel brucellosis, these are at animal level: habitat, herd size, cohabitation with other ruminants, and contact with other camels, the latter indicating an intercamel cycle. At herd level, the risk factors are herd size and cohabitation with other ruminants.^{28,29} Further risk factors are the increase in species composition at household level, and the wet season.³⁰ Camels appear to become infected via spill-over from small ruminants and cattle.³ This observation is supported by the fact that all *Brucella* spp. and biovars infecting other ruminants have also been isolated from camels (Tables 1 and 2). However, the final proof by means of genotyping is still missing.

Since camels suffer from lack of attention and negligence in numerous countries, the control of brucellosis in camels is severely hampered. Several approaches could be applied to improve the situation and significantly reduce the occurrence of brucellosis in camels, among them are: encouragement of closer interaction between animal keepers and veterinary personnel, as well as the establishment of a common vocabulary for camel diseases and conditions;³¹ introduction of hygiene procedures and correct disposal of aborted materials and the use of disinfectants;²⁸ a sensible intersectional collaboration between public health and veterinary sectors based on the concept of 'one medicine'³² which would greatly improve the health status both in animals and humans;^{33,34} intergovernmental cooperation between trading countries to prevent cross border transmission;⁶ mass testing with appropriate techniques and culling accompanied by adequate compensation (livestock), introduction of rational vaccination schemes^{22,35} and application of antibiotics.³ Although these suggestions have been made by numerous scientists for many years, hardly any have been implemented outside from study set ups and NGO projects and the general situation has not greatly improved.

Despite vaccination campaigns, *B. melitensis* remains the principal cause of human brucellosis.²² A synopsis of the seroprevalence of *Brucella* in humans in some

North- and sub-Saharan countries is shown in Table 4. Numerous risk factors have been determined for human camel-derived brucellosis: consumption of unpasteurized camel milk and buttermilk³⁶⁻⁴⁰ and unpasteurized dairy products,^{36,41} camel ownership,⁴² assistance during animal parturition^{42,43} and the presence of further infected family members.^{41,44}

A number of studies have reported that the highest prevalences can be found in males;^{42,44,45} however, studies from Saudi Arabia, Oman, and Jordan have shown that, contrary to common belief, children can also be strongly affected by brucellosis with prevalences between 21 and 70%.^{38,46,47} The male predominance is most likely related to occupational exposure,⁴² whereas children usually have a history of raw milk ingestion, consumption of unpasteurized milk products or in very rare cases animal contact.⁴⁸ Since infection with camel brucellosis is predominantly caused by the ingestion of raw milk and products made thereof, boiling the milk prior to consumption and processing would be an easy and efficient preventive measure. However, boiling of milk, irrespective of its origin, i.e. goat, sheep, or camel, is believed to spoil the taste and remove its goodness and healing capacities.³⁷ Implementing heat treatment of milk is therefore very challenging, as local dietary customs are deeply engrained in society,³⁷ nevertheless, consumer consciousness regarding milk hygiene must be raised, e.g. at school, in hospitals and through community based (animal) health workers.^{4,49} Building of milking parlours, as has been performed in Dubai, provides a means for obtaining and distributing high quality products; however, the majority of camel rearing countries simply do not have the necessary financial means.

Economic Impact

In times of increasing human population, more resources are needed and camels are an ideal asset. Not only do they function as power suppliers (drawing water, grinding wheat, ploughing, etc.) and act as transport medium, they are vital sources of milk and inexpensive meat which are not only consumed

Table 4 Seroprevalence of human brucellosis in some North and sub-Saharan African countries*

Country	No. of samples	Test	Prevalence (%)	Reference
Sudan	20 (nomads)	RBPT	60	56
	33 (abattoir workers)		9	
Tanzania	199	RBPT	5.52	68
Libya	546	RBPT/ELISA	40	34
Egypt	150	RBPT/ELISA	32.3	69
Egypt	10,130	SLA	3	45
Chad	860	iELISA	3.9	33
Ethiopia	653 (outpatients clinic)	SAT	2.6	70
Ethiopia	336 (occupationally exposed)	RBPT/2-MET	4.8	71

Note: *No data were obtainable from central Asia and China (with the exception of Mongolia).

RBPT: Rose Bengal plate test; CFT: complement fixation test; iELISA: indirect ELISA; SAT: serum agglutination test; 2-MET: beta-mercaptoethanol test.

locally, but also exported to numerous countries.⁵⁰ Consequently, a disease like brucellosis, besides having a major impact on a country's economy, can have devastating effects on human health.³⁵ The economic impact of brucellosis on camels can be estimated on the basis of losses due to morbidity and mortality and by estimating treatment costs.³⁵ In order to estimate human morbidity and mortality losses, disability-adjusted life-years are applied, which are based on data obtained from human brucellosis control programs. By combining data on the years of life lost and years of life with disability the disability-adjusted life-years are calculated. The chronic nature of the disease and the difficulties arising when treating patients must also be taken into consideration when calculating costs to local health services.³⁵ For further reading, the authors recommend the study conducted by Roth *et al.*⁵¹ supplying further information on brucellosis control decision-making.

Ignoring the impact of a zoonotic disease in a population comprising nearly 26 million animals with the ability to spread in to a human population encompassing approx. 1050 million people in Africa and 2870 million in Asia (without China) is an act of gross negligence. Every effort should therefore be made to increase awareness of this disease in animal keepers, consumers of camel products, public and veterinary health authorities, and decision makers.

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