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REGULAR ARTICLES

MERS and the dromedary camel trade between Africa and the Middle East

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Abstract Dromedary camels are the most likely source for the coronavirus that sporadically causes Middle East respiratory syndrome (MERS) in humans. Serological results from archived camel sera provide evidence for circulation of MERS coronavirus (MERS-CoV) among dromedary camels in the Greater Horn of Africa as far back as 1983 and in Saudi Arabia as far back as 1992. High seroprevalences of MERS-CoV antibodies and the high virus prevalence in Saudi Arabian dromedary camels indicate an endemicity of the virus in the Arabian Peninsula, which predates the 2012 human MERS index case. Saudi Arabian dromedary camels show significantly higher MERS-CoV carrier rates than dromedary camels imported from Africa. Two MERS-CoV lineages identified in Nigerian camels were found to be genetically distinct from those found in camels and humans in the Middle East. This supports the hypothesis that camel imports from Africa are not of significance for circulation of the virus in camel populations of the Arabian Peninsula.

Keywords MERS · Coronavirus · Dromedary camels · Trade · Africa · Arabian Peninsula

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Introduction

In reaction to the ongoing Middle East respiratory syndrome (MERS) outbreak in humans, caused by the betacoronavirus group C MERS virus (Zaki et al. 2012; Bermingham et al. 2012; Chu et al. 2014), a ban on imports of MERS-positive dromedary camels (*Camelus dromedarius*) has been discussed in the Kingdom of Saudi Arabia (KSA). Since May 2014, imported camels are being tested for MERS in the United Arab Emirates (UAE) and certain restrictions on imports of a small number of MERS-positive camels have been enforced by Iran (OIE 2014).

Over 60 % of the worlds' dromedary camels are kept by pastoralists in the Greater Horn of Africa (GHA), with Somalia alone accounting for one third of the world population (Faye 2013). For these pastoral communities, camels play a major role as milk providers while sales of camels for export are an important source of income. This paper discusses whether import restrictions for camels originating in the GHA can make a meaningful contribution towards reducing the risk of clinical MERS in humans.

Economic importance of camel exports from the GHA and major trade routes

Dromedary camel trade from Somalia to the Arabian Peninsula has been documented since 1884 (Castiello et al. 2012). Oil wealth and urbanisation are driving the demand for camel meat with increasing numbers of camels being imported into the Arabian Peninsula from the GHA and Sudan. In addition, Sudanese racing dromedaries have been traded to the KSA and the UAE via Egypt since the 1950s (Nawata 2005).

In semi-arid Africa, the highest camel population densities overlap geographically with those areas where the poorest households are located (Sebastian 2014). Camels valued at about USD 1000 per adult animal represent the most valuable livestock export species in the GHA, and their sales inject significant amounts of cash into the pastoral economy. The largest cross-border camel trade globally is the trekking and shipment of camels for slaughter from countries in the GHA to Egypt, the KSA, Qatar, the UAE, Yemen, Libya and also Bahrain (Aklilu 2002; Aklilu and Catley 2009; Mahmoud 2010; Castiello et al. 2012). The estimated number of camels exported annually from Somalia and Sudan varies between 250,000 and 300,000 (Aklilu 2002; Castiello et al. 2012). In 2012, 304,681 camels were officially exported by Intergovernmental Authority on Development (IGAD) member states, mainly Somalia and Sudan, to the Middle East and to the North Africa representing an estimated trade value of 365,000,000 USD (Dr. A. Sebsibe, IGAD/ICPALD Director Livestock, personal communication 2015, ameha.sebsibe@igad.int). According to FAO (2015), the highest livestock exports ever recorded for Somalia were in 2014, including 77,000 camels, while 72,000 camels were exported from Somalia in 2015 (FAO 2016a).

The Birqash market near Cairo is the largest camel market in Africa. Egypt receives camels from Sudan, Somalia, Ethiopia, Eritrea, and via Ethiopia and also from Kenya (Muthee 2006; Mahmoud 2010; Catley et al. 2013). Camels from Ethiopia and Somalia reach Egypt via the Red Sea ports of Safaga and Suez (Sayour et al. 2015). Some Sudanese camels are still trekked to Egypt via the traditional "Fourties" route, but the larger numbers of camels are nowadays transported from Sudan to Egypt by lorry. Camels from Chad are also traded to Egypt via Sudan (Kadim et al. 2013). Somali camels destined for the KSA are shipped mainly from the ports of Berbera and Bosaso in North Somalia to the KSA Red Sea ports of Jizan and Djeddah. Most of the camel trade from Sudan and Somalia to the KSA is handled by large livestock companies. Al-Jabri, the largest Saudi Arabian livestock import company, handles 60 % of Sudanese livestock exports to the KSA (http://en.aljabri.com.sa/?page_id=4180). The joint Al-Jabri Ras-al-Khaimah "Saudi-Emirati company for managing and operating veterinary quarantines" has its' own veterinary quarantine stations and veterinary laboratories for certification of export livestock at the Somali ports of Berbera and Bosaso. In addition, the Al-Jabri company operates a large quarantine zone in Al-Khomra near Jeddah, which is supervised by the veterinary authorities of the KSA Ministry of Agriculture.

MERS in camels

The fact that significant clinical disease is not recognised in relation to MERS-CoV in dromedary camels indicates a well-established balance between the camel host and the MERS-CoV. A limited experimental infection of naive camels with MERS-CoV produced only mild symptoms (Adney et al. 2014). Reported natural MERS field cases in suckling camel calves are very mild with a brief viraemic phase. Suckling camel calves aged up to 1 year represent the most important source for MERS-CoV in dromedary camel populations of the KSA (Chu et al. 2014; Hemida et al. 2014; Sabir et al. 2016). Serological findings from Kenya (Deem et al. 2015) indicate that camel calves below 6 months of age have a significantly higher MERS-CoV antibody prevalence (39.3 % seropositive) than camel calves aged above 6 months (21.3 % seropositive), very likely reflecting the waning of maternal colostral MERS-CoV antibodies in suckling camel calves. Up to 100 % MERS-CoV antibody seropositivity has been found in archived camel sera, demonstrating endemic presence of MERS-CoV in camel populations in Somalia since 1983, in Sudan since 1984, in Egypt since 1997, in Kenya from 1992 to 2013 (Müller et al. 2014; Corman et al. 2014), in the KSA since 1992/1993 (Alagaili et al. 2014) and in the UAE for at least one decade (Meyer et al. 2014; Alexandersen et al. 2014). MERS antibody-positive camels are also reported from Oman, Nigeria, Tunisia, Ethiopia, Jordan and the Canary Islands (Reusken et al. 2014a, b). The limited number of Bactrian camels (*Camelus bactrianus*) tested in Mongolia and in Kazakhstan were all seronegative for MERS-CoV (Chan et al. 2015; Miguel et al. 2016). Seronegative dromedary camel populations have so far only been found in Australia (Crameri et al. 2015) and in Kazakhstan (Miguel et al. 2016). No information on MERS in camels has been published from Afghanistan, Pakistan or India, despite the fact that these countries have significant dromedary camel populations.

It is noteworthy that MERS-CoV antibody seropositivity and percentages of MERS-CoV RNA-positive camels do not show clustering around the two major KSA livestock import ports of Jeddah and Gizan where an increased likelihood of contacts between imported African dromedary camels and local Saudi Arabian dromedary camels can be expected (Alagaili et al. 2014). Screening of trade camels by PCR at KSA markets revealed a higher MERS-CoV carrier rate in local KSA camels as compared to camels imported from Sudan and Somalia (Sabir et al. 2016, see Table 1). One uncertainty of these findings is the extent to which imported camels had been exposed to local KSA camels at markets, holding grounds or fattening farms before the actual sampling was carried out.

Of 110 imported mostly Sudanese camels screened at two abattoirs in Egypt, 93.6 % were MERS-CoV seropositive (Perera et al. 2013) while only 3.6 % were positive for MERS-CoV in the PCR (Chu et al. 2014). Similar to the practice in the KSA, these imported camels had been kept at local farms in Egypt for fattening before slaughter.

Table 1 MERS-CoV prevalence in trade camels in Saudi Arabian Camel Markets (adopted from Sabir et al. 2016)

Country of origin	Number of camels sampled	MERS-CoV PCR-positive camels
KSA	893	133 (14.9 %)
Sudan	116	7 (6.0 %)
Somalia	291	19 (6.5 %)

Characterisation of MERS-CoV isolated from camels in Nigeria (Chu et al. 2015) revealed the existence of two lineages of Sub-Saharan MERS-CoV, which are genetically distinct from viruses found in camels in the Middle East and from viruses detected in humans in more recent years.

Human MERS

Dromedary camels can act as a source of human MERS-CoV infections (Reusken et al. 2015), but the main risk factors for clinical human MERS-CoV infections are still not fully understood (Mackay and Arden 2015). The MERS-CoV is poorly transmissible from camels to humans, and clinical human MERS disease is not proportional to potential exposure of humans to virus circulation in camels (Hemida et al. 2015). The mean age of MERS-CoV-seropositive individuals was significantly lower than that of patients with confirmed clinical MERS (Müller et al. 2015). MERS-CoV is suspected of causing subclinical or only very mild infections in healthy younger individuals (15–44 years) who may then act as a source of infection for clinical MERS in elderly humans that have not had contact with camels (Müller et al. 2015). MERS-CoV antibody seroprevalence rates in cross-sectional studies of healthy humans in KSA ($n = 10,009$) and in a camel keeping region of North Kenya ($n = 1122$) were 0.15 and 0.18 %, respectively (Müller et al. 2015; Liljander et al. 2016). In the KSA, MERS-CoV seroprevalence was 15 times higher in camel herders and 23 times higher in slaughterhouse workers as compared to the general human population (Müller et al. 2015), and camel farm workers in Qatar also had a higher MERS-CoV seroprevalence than occupationally less exposed individuals (Reusken et al. 2015). A MERS risk model based on human exposure rates to camels, developed by PREDICT (Dr. William Karesh personal communication at the January 2016 FAO MERS workshop http://www.vetmed.ucdavis.edu/ohi/predict/), calculated a much higher MERS-CoV seroprevalence for camel pastoralists than the seroprevalence documented by Liljander et al. (2016) in a pastoralist region in Kenya. Potential exposure to live camels (or other animals) has only been documented for 7.6 % of all human MERS cases (FAO 2016b). Observations from the recent human MERS outbreak in the Republic of Korea strongly support the hypothesis that the health care environment plays a crucial role in the epidemiology of human MERS; the primary case in the Republic of Korea had travelled to the Middle East but had not had any contact with camels; all 186 confirmed human MERS cases in the Republic of Korea (leading to 36 deaths) originated from health care facilities (WHO 2015).

Discussion

Given that a substantial proportion of dromedary camel exports moves through formalised trade channels, screening of the MERS-CoV carrier state of export camels before shipment appears theoretically feasible. One major drawback for such a screening is the fact that MERS-CoV PCR-negative camels imported into the KSA, Egypt or other Gulf countries would certainly be exposed to local MERS-CoV-positive camels at fattening farms, holding yards and camel markets. At present, no MERS control measures are foreseen in KSA camels that aim at significantly reducing the MERS-CoV prevalence in the national camel herd. An orthopoxvirus-based MERS vaccine tested in camels reduced virus shedding but did not halt multiplication and excretion of virus in the upper respiratory tract (Haagmans et al. 2016). It also remains unclear what such a potential MERS vaccination is expected to achieve, given the high natural levels of anti MERS-CoV antibodies in KSA camels. Controlling an endemic coronavirus in millions of mobile nomadic camels would represent an even more difficult if not unrealistic task than in the more farm-based KSA dromedary camel population. The unidirectional trade in dromedary camels from the GHA to the Middle East is taking place between two regions whose camel populations have been harbouring MERS-CoV for several decades. From past RVF outbreaks in the KSA, the devastating economic impacts and the inefficacy of livestock export bans in controlling the spread of zoonotic animal diseases are well documented for East Africa and the Middle East (Pratt et al. 2005; Antoine-Moussiaux et al. 2012).

Phylogenetic analysis points towards the emergence of a new zoonotic MERS-CoV in 2011 (Drosten et al. 2013), which may have taken place in the KSA. The identification of a MERS-CoV lineage in camels in Sub-Saharan Africa that is genetically distinct from MERS-CoV lineages causing human MERS in the Middle East (Chu et al. 2015) adds further complexity to the epidemiologic picture. In addition, Egypt which routinely imports MERS-positive camels from Sudan, Ethiopia and Somalia, is yet to report autochthonous clinical human MERS. In the absence of a clear understanding of the different lineages of MERS-CoV in geographically separate dromedary camel populations and their potential pathogenicity for humans, there is at present a complete lack of evidence that camel trade restrictions between GHA and the Middle East would have any impact on the MERS risk for humans in the Arabian Peninsula. The only camel keeping countries that should perhaps consider movement and trade restrictions for MERS-positive camels are obviously Kazakhstan, Mongolia and Australia. Surveillance for MERS-CoV in camels needs to be urgently intensified in all camel-keeping countries, especially in those Asian countries with a complete lack of data on the MERS status of their camel populations. Comparative studies of MERS-CoV isolates from all camel-keeping regions are urgently required to better understand potential differences between regional MERS-CoV lineages in terms of their infectiousness and pathogenicity for humans.

Neither the FAO 2014 MERS meeting in Oman (FAO 2014) nor the 2016 FAO MERS workshop in Rome (FAO 2016c) called for camel trade restrictions. The 2016 FAO MERS workshop in Rome (FAO 2016c) rather pointed out that no autochthonous clinical human MERS cases have been reported from Africa and emphasised the need for a better understanding of MERS-CoV transmission patterns. In the MERS update on 22 April 2016, the WHO does not recommend travel or trade restrictions in relation to MERS but advocates for persons that are immunocompromised or suffer from diabetes, renal failure, or chronic lung disease to avoid close contact with camels (WHO 2016), in line with earlier recommendations (Mackay and Arden 2015). Should a MERS vaccine for humans become available (Zhou et al. 2014; Muthumani et al. 2015), it could not only provide additional protection for high risk groups but possibly also prevent the very sporadic zoonotic transmission of MERS-CoV from camels to professionally exposed camel herders and slaughterhouse workers.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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