

# Acute Middle East Respiratory Syndrome Coronavirus Infection in Livestock Dromedaries, Dubai, 2014

Ulrich Wernery, Victor M. Corman,  
Emily Y.M. Wong, Alan K.L. Tsang, Doreen Muth,  
Susanna K.P. Lau, Kamal Khazanehdari,  
Florian Zirkel, Mansoor Ali, Peter Nagy,  
Jutka Juhasz, Renate Wernery, Sunitha Joseph,  
Ginu Syriac, Shyna K. Elizabeth,  
Nissy Annie Georgy Patteril, Patrick C.Y. Woo,  
Christian Drosten

Camels carry Middle East respiratory syndrome coronavirus, but little is known about infection age or prevalence. We studied >800 dromedaries of all ages and 15 mother–calf pairs. This syndrome constitutes an acute, epidemic, and time-limited infection in camels <4 years of age, particularly calves. Delayed social separation of calves might reduce human infection risk.

Middle East respiratory syndrome coronavirus (MERS-CoV) causes outbreaks and isolated cases of severe respiratory disease in humans. The virus is transmissible from human to human, but the focus of infection has remained in countries on the Arabian Peninsula. Recent reports have shown that dromedaries (*Camelus dromedarius*) across the Arabian Peninsula and parts of eastern and northern Africa have MERS-CoV antibodies (1–4). Virus detection by reverse transcription PCR (RT-PCR) and sequencing has confirmed that these antibodies are likely to be caused by infection with the same virus strains that infect humans (5). In singular cases, strong evidence for virus transmission between camels and humans was found (6,7). Infection of dromedaries in the laboratory has confirmed susceptibility and efficient shedding (8). MERS-CoV antibodies were not found in other species of livestock and leisure animals, including cattle, goats, sheep, and horses (9).

Author affiliations: Central Veterinary Research Laboratory, Dubai, United Arab Emirates (U. Wernery, K. Khazanehdari, R. Wernery, S. Joseph, G. Syriac, S.K. Elizabeth, N.A. Georgy Patteril); University of Bonn Medical Centre, Bonn, Germany (V.M. Corman, F. Zirkel, C. Drosten); German Centre for Infection Research, Bonn (V.M. Corman, F. Zirkel, C. Drosten); University of Hong Kong, China (E.Y.M. Wong, A.K.L. Tsang, D. Muth, S.K.P. Lau, P.C.Y. Woo); Dubai Camel Hospital, Dubai (M. Ali); Emirates Industry for Camel Milk and Products, Dubai (P. Nagy, J. Juhasz)

DOI: <http://dx.doi.org/10.3201/eid2106.150038>

In the absence of a MERS-CoV vaccine, the prevention of human infections relies on knowledge of acute infection in camels. Available serologic studies indicate a high prevalence of MERS-CoV in adult camels, suggesting that MERS-CoV infection in camels may target young animals (1–4). However, only limited data on the age of animals at infection and the degree of age-specificity are available (5).

To best approximate the actual infectivity of virus in camels, testing should include RT-PCR and systematic virus isolation in cell culture (10). We recently analyzed a small group of camels in Saudi Arabia and found signs of recent acute MERS-CoV infection by demonstrating seroconversion, indicating a method for the serologic diagnosis of acute infection (7). To increase knowledge of acute MERS-CoV in dromedaries, we analyzed acute- and convalescent-phase MERS-CoV infections in similarly sized groups of camels of the same age in Dubai, United Arab Emirates.

## The Study

We investigated dairy, racing, and breeding dromedaries from 3 flocks on farms 20–40 km apart. When possible, blood and nasal swab specimens were obtained from all camels in the flocks during March–June 2014. Samples were grouped according to the camels' ages rather than sampling site because livestock ages differed between sites. Serologic testing by ELISA yielded evidence of MERS-CoV antibodies in >96% of all dromedaries >2 years of age (Table 1). Seroprevalence among dromedaries <1 year of age (calves) was significantly lower but still exceeded 80%. Using cross-sectional testing, we could not discriminate between maternal and autonomous antibodies in calves. RT-PCR testing of nasal swab specimens showed a considerable prevalence of MERS-CoV RNA among all dromedaries <4 years of age but particularly in calves. Similarly, virus isolation conducted on all samples, including those RT-PCR–negative for MERS-CoV (14), was successful only for animals <4 years of age but particularly for calves. The prevalence of virus RNA and the rate of virus isolation were significantly higher in calves than subadults (2–4 years of age) ( $\chi^2$ ,  $p<0.05$ ). The higher rate of virus isolation among calves suggests increased infectivity of calves.

To understand MERS-CoV infection in dromedary calves, we investigated 24 mother–calf pairs from the

**Table 1.** Results of cross-sectional study of MERS-CoV antibodies and RNA and MERS-CoV isolation in dromedary camels at 3 sampling sites, Dubai, March–June, 2014\*

Age group, y	Mean no. positive/no. tested (% positive)		
	Serum antibody detection by ELISA†	RNA detection by RT-PCR‡	Virus isolation§
Adults, >4	298/310 (96.1)	0/250 (0)	0/12 (0)
Subadults, 2–4	328/340 (96.5)	10/344 (2.9) ¶	1/14 (7.1)
Calves, <1	92/108 (85.2) ¶¶	24/68 (35.3) ¶¶	6/44 (13.6) ¶¶
Unknown	68/85 (80)	11/209 (5.3)	1/12 (8.3)
Total	786/843 (93.2)	45/871 (5.1)	8/82 (9.6)

\*MERS-CoV, Middle East respiratory syndrome coronavirus; RT-PCR, reverse transcription PCR.  
†ELISA used a recombinant MERS-CoV globular spike (S1) domain as described by Drosten et al. (11), modified by the reagent manufacturer (EUROIMMUN, Lübeck, Germany) for application with camel serum as validated by Corman et al. (12) and Memish et al. (7). The anti-human conjugate was replaced by an anti-camel conjugate. The test was not selective for IgG.  
‡RT-PCR targeting regions upstream of the envelope gene, as described by Corman et al. (13).  
§Method as described by Drosten et al. (14).  
¶Significantly different from grand mean (shown under Total),  $p < 0.05$  ( $\chi^2$  test)

breeding flock. The investigations were all conducted in May 2014. At the time of sampling, mother camels were >12–15 years of age, and calves were 4–6 months of age. As shown in Table 2, all cows were MERS-CoV antibody positive and had no signs of active MERS-CoV infection by RT-PCR and virus isolation. Of the 15 calves

studied, 4 showed evidence of ongoing seroconversion during sampling days 0 and 8; on day 8, all calves were seropositive by ELISA. On sampling day 0, virus was detected in 11/15 (73.3%) calves, and on sampling day 8, it was detected in 4/15 (26.7%) calves. This overall pattern was suggestive of a recent infection peak in the flock that was

**Table 2.** Results of testing for the presence of MERS-CoV and MERS-CoV antibody in 15 mother–calf pairs in a dromedary breeding flock, Dubai, May 2014\*

Camel	Antibody ELISA		Virus isolation		PCR, threshold cycle	
	Day 0	Day 8	Day 0	Day 8	Day 0	Day 8
<b>Mother</b>						
M1	+	ND	–	ND	–	ND
M2	+	ND	–	ND	–	ND
M3	+	ND	–	ND	–	ND
M4	+	ND	–	ND	–	ND
M5	+	ND	–	ND	–	ND
M6	+	ND	–	ND	–	ND
M7	+	ND	–	ND	–	ND
M8	+	ND	–	ND	–	ND
M9	+	ND	–	ND	–	ND
M10	+	ND	–	ND	–	ND
M11	+	ND	–	ND	–	ND
M12	+	ND	–	ND	–	ND
M13	+	ND	–	ND	–	ND
M14	+	ND	–	ND	–	ND
M15	+	ND	–	ND	–	ND
Total	15	NA	0	NA	0	NA
<b>Calf</b>						
C1	±	+	+	–	19.5	–
C2	+	+	–	–	–	–
C3	+	+	–	–	24.3	–
C4	–	+	–	–	26.8	32.3
C5	±	+	–	–	30.4	–
C6	–	+	–	–	26.5	–
C7	+	+	–	–	–	–
C8	+	+	–	–	–	–
C9	+	+	+	–	23.8	–
C10	+	+	+	–	24.1	–
C11	+	+	+	–	22.3	34.2
C12	+	+	–	–	–	–
C13	+	+	–	–	22.8	34.2
C14	+	+	+	–	20.7	–
C15	+	+	–	–	32.4	35.3
Total	11 (+2)	15	5	0	11	4

\*MERS-CoV, Middle East respiratory syndrome coronavirus; NA, not applicable; ND, not done; +, positive; –, negative; ±, weak positive (borderline optical density range as identified by the reagent manufacturer, EUROIMMUN, Lübeck, Germany).



results suggest excretion to be short lived in individual camels. Of the 11 virus-positive calves, 5 had high virus RNA concentrations in their first samples (cycle threshold values <25) but no RNA in samples tested 8 days later. An infection experiment in adult dromedaries showed shedding occurred for  $\leq 35$  days after virus inoculation (8), which seems longer than the length of virus shedding observed for young camels in our study. However, detection sensitivity in the defined conditions of a laboratory trial might have been higher than in our study. Both studies agreed in their finding of short-lived infectivity of excreted virus: in our study, we did not detect virus in any calf on day 8, and none were detected beyond day 7 in the study by Adney et al. (8). Nevertheless, virus can be maintained in flocks over several weeks or months, as exemplified by the detection of the same virus clade in March and June on 1 dairy farm.

The restricted and highly compartmentalized social structure of livestock camels would provide population niches in which viruses can differentiate in isolation after bottleneck-type transmission events. This situation holds promise for control of the spread of MERS-CoV through flock management practices, and it also suggests a rather simple way of avoiding camel-to-human transmission by avoiding camels <2 years of age. Camel calves are not easily accessible by humans and instinctually avoid humans. They are generally separated from their mothers after 12 months of age (i.e., at an age when they are still likely to be infected with MERS-CoV). Humans normally come into contact with calves only after the animals have been separated from their mothers. A change in this practice (i.e., postponing separation until the calves are older) might reduce the risk for camel-to-human MERS-CoV transmission.

### Acknowledgments

We thank Monika Eschbach-Bludau, Sebastian Brünink, Tobias Bleicker, and Artem Siemens for excellent technical assistance.

This work was partly supported by the Seed Funding for Theme-Based Research Scheme and Strategic Research Theme Fund, The University of Hong Kong; Research Grant Council Grant, University Grant Council; and Consultancy Service for Enhancing Laboratory Surveillance of Emerging Infectious Disease of the Hong Kong Special Administrative Region Department of Health. Work in Bonn was funded by the European Commission ANTIGONE (Anticipating the Global Onset of Novel Epidemics) project (contract no. 278976) and the Deutsche Forschungsgemeinschaft (grant DR 772/7-1 to C.D.).

Dr. Wernery, a veterinary microbiologist, is head of the Central Veterinary Research Laboratory in Dubai, United Arab Emirates. His main research interest is infectious diseases of livestock, in particular camels, of the Arabian Peninsula.

### References

1. Reusken CB, Messadi L, Feyisa A, Ullaramu H, Godeke GJ, Danmarwa A, et al. Geographic distribution of MERS coronavirus among dromedary camels, Africa. *Emerg Infect Dis.* 2014;20:1370–4. <http://dx.doi.org/10.3201/eid2008.140590>
2. Meyer B, Muller MA, Corman VM, Reusken CB, Ritz D, Godeke GJ, et al. Antibodies against MERS coronavirus in dromedary camels, United Arab Emirates, 2003 and 2013. *Emerg Infect Dis.* 2014;20:552–9. <http://dx.doi.org/10.3201/eid2004.131746>
3. Reusken CB, Haagmans BL, Muller MA, Gutierrez C, Godeke GJ, Meyer B, et al. Middle East respiratory syndrome coronavirus neutralising serum antibodies in dromedary camels: a comparative serological study. *Lancet Infect Dis.* 2013;13:859–66. [http://dx.doi.org/10.1016/S1473-3099\(13\)70164-6](http://dx.doi.org/10.1016/S1473-3099(13)70164-6)
4. Müller MA, Corman VM, Jores J, Meyer B, Younan M, Liljander A, et al. MERS coronavirus neutralizing antibodies in camels, eastern Africa, 1983–1997. *Emerg Infect Dis.* 2014;20:2093–5. <http://dx.doi.org/10.3201/eid2012.141026>
5. Alagaili AN, Briese T, Mishra N, Kapoor V, Sameroff SC, Burbelo PD, et al. Middle East respiratory syndrome coronavirus infection in dromedary camels in Saudi Arabia. *MBio.* 2014;5:e00884–14. <http://dx.doi.org/10.1128/mBio.01002-14>
6. Haagmans BL, Al Dhahiry SH, Reusken CB, Raj VS, Galiano M, Myers R, et al. Middle East respiratory syndrome coronavirus in dromedary camels: an outbreak investigation. *Lancet Infect Dis.* 2014;14:140–5. [http://dx.doi.org/10.1016/S1473-3099\(13\)70690-X](http://dx.doi.org/10.1016/S1473-3099(13)70690-X)
7. Memish ZA, Cotten M, Meyer B, Watson SJ, Alshahfi AJ, Al Rabeeah AA, et al. Human infection with MERS coronavirus after exposure to infected camels, Saudi Arabia, 2013. *Emerg Infect Dis.* 2014;20:1012–5. <http://dx.doi.org/10.3201/eid2006.140402>
8. Adney DR, van Doremalen N, Brown VR, Bushmaker T, Scott D, de Wit E, et al. Replication and shedding of MERS-CoV in upper respiratory tract of inoculated dromedary camels. *Emerg Infect Dis.* 2014;20:1999–2005. <http://dx.doi.org/10.3201/eid2012.141280>
9. Reusken CB, Ababneh M, Raj VS, Meyer B, Eljarah A, Abutarbush S, et al. Middle East respiratory syndrome coronavirus (MERS-CoV) serology in major livestock species in an affected region in Jordan, June to September 2013. *Euro Surveill.* 2013;18:20662.
10. Raj VS, Farag EA, Reusken CB, Lamers MM, Pas SD, Voermans J, et al. Isolation of MERS coronavirus from a dromedary camel, Qatar, 2014. *Emerg Infect Dis.* 2014;20:1339–42. <http://dx.doi.org/10.3201/eid2008.140663>
11. Drosten C, Meyer B, Muller MA, Corman VM, Al-Masri M, Hossain R, et al. Transmission of MERS-coronavirus in household contacts. *N Engl J Med.* 2014;371:828–35. <http://dx.doi.org/10.1056/NEJMoa1405858>
12. Corman VM, Jores J, Meyer B, Younan M, Liljander A, Said MY, et al. Antibodies against MERS coronavirus in dromedary camels, Kenya, 1992–2013. *Emerg Infect Dis.* 2014;20:1319–22. <http://dx.doi.org/10.3201/eid2008.140596>
13. Corman VM, Eckerle I, Bleicker T, Zaki A, Landt O, Eschbach-Bludau M, et al. Detection of a novel human coronavirus by real-time reverse-transcription polymerase chain reaction. *Euro Surveill.* 2012;17:20285.
14. Drosten C, Muth D, Corman VM, Hussain R, Al Masri M, Hajomar W, et al. An observational, laboratory-based study of outbreaks of MERS-coronavirus in Jeddah and Riyadh, Kingdom of Saudi Arabia, 2014. *Clin Infect Dis.* 2015;60:369–77. <http://dx.doi.org/10.1093/cid/ciu812>
15. Hemida MG, Chu DK, Poon LL, Perera RA, Alhammedi MA, Ng HY, et al. MERS coronavirus in dromedary camel herd, Saudi Arabia. *Emerg Infect Dis.* 2014;20:1231–4. <http://dx.doi.org/10.3201/eid2007.140571>

Address for correspondence: Ulrich Wernery, Central Veterinary Research Laboratory, PO Box 597, Dubai, United Arab Emirates; email: cvrl@cvrl.ae