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SHORT REPORT: EXPOSURE TO HUMAN RESPIRATORY VIRUSES AMONG URBAN PERFORMING MONKEYS IN INDONESIA

MICHAEL A. SCHILLACI, LISA JONES-ENGEL,* GREGORY A. ENGEL, AND RANDALL C. KYES

Department of Social Sciences, University of Toronto at Scarborough, Scarborough, Ontario, Canada; Washington National Primate Research Center, University of Washington, Seattle, Washington; Swedish/Providence Family Medicine Residency, Seattle, Washington

Abstract. Performing monkeys, a common phenomena in Asia, occupy a unique urban niche that comprises a number of factors influencing the likelihood of cross-species transmission of pathogens. Here we present the first documented evidence of exposure to measles, rubella, and parainfluenza in a population of performing monkeys. Evidence of exposure to these endemic human respiratory viruses in the performing monkeys confirms human-to-primate transmission and suggests the possibility of primate-to-human transmission. Urban animal markets, the likely source of these performing monkeys, may represent an environment conducive to the mixing of animals and pathogens, making these monkeys a potential conduit for infectious agents passing from a variety of animals found in animal markets to humans. The potential significance of these results to human public health and the unique contexts of disease transmission associated with the urban ecology of the performance monkeys are discussed. Given the level of overseas travel, this potential threat is not confined solely to Asia.

INTRODUCTION

Zoonotic diseases are increasingly recognized as emerging biologic threats to human health, yet relatively little is known about how pathogens actually jump from one species to another. The World Health Organization (WHO) Coordinator for the Global Outbreak and Response Network, Dr. Mike Ryan, referring to the severe acute respiratory syndrome (SARS) epidemic in a recent 2003 radio interview (http://www.npr.org/news/specials/sars/ryan.html), alluded to the lack of data describing how human–animal interactions influence the emergence of zoonotic disease.

". . . infectious diseases occur in an ecological context. It may have something to do with our interaction with the animals . . . and what happened at the animal–human interface . . . we really don't understand that adequately."

As we strive to increase our understanding of this vital link in the chain of emerging infectious diseases, it is important that we take a global view of the diverse contexts of cross-species pathogen transmission, taking into account the pathogens involved, the animal reservoirs of those pathogens, the human populations that are potential new hosts for those pathogens, and the diverse and complex ways in which the three interrelate.

Non-human primate (NHP)-to-human zoonotic transmission is a prescient concern, given the recent emergence of NHP-borne infectious agents into human populations.[1–4] Cross-species disease transmission is a particularly salient issue in Asia, where dense human populations live in close proximity with a large and diverse NHP fauna. Humans come into contact with NHPs in a variety of contexts in Asia, including monkey forests, bushmeat hunting, NHP pet ownership, and ecotourism. Here we explore a context of NHP–human contact that has received little attention in the scientific literature, that is, human contact with performing monkeys.[5]

Although performing NHPs are encountered throughout the world, Asian cultures have perhaps the longest and most vibrant tradition of using NHPs for entertainment (Figure 1). Notable examples include the Suo-Sarumawashi (Japanese Monkey Performance School), which has a 1,000-year history of training performance monkeys.[6] Similar training schools can be found throughout South and Southeast Asia, where monkeys play an important role in Hindu and Buddhist cultures. Performing monkeys are also obtained and trained by individuals or communities that derive their livelihood by exhibiting the performing monkeys in urban settings.

The ecology of performance monkeys is distinct from that of other urban NHPs that come into contact with humans in other contexts, such as temple or park monkeys, pet NHPs, zoo and laboratory NHPs, and NHPs sold at pet and food markets.[1,5,7] The acquisition of performing monkeys, the care they receive from their trainers, the characteristics of the urban environments they typically inhabit, and the unique circumstances of the performances themselves are aspects of the performance monkey "niche."[5]

Research suggests that pathogens may be transmitted from pet monkeys to humans and from humans to pet monkeys.[8–11] Once performance monkeys are acquired by their owners, they occupy a "niche" similar to that of pets, but with the important added feature of frequent contact with audiences, which are typically urban. On one hand, these monkeys have frequent, intensive exposure to their owners and the owners' families, as well as other domestic animals that occupy their compound. On the other, they come into close proximity and often contact with large numbers of audience members. As part of a performance, monkeys may have several kinds of physical contact with the audience, including climbing onto shoulders, hand-to-hand contact, and even kissing. These close contacts present an opportunity for the human-to-NHP as well as NHP-to-human transmission of infectious agents.

Several of the performing monkeys (*Macaca fascicularis*) in this study were originally obtained from animal markets, most likely Pramuka, the large bird and animal market that has been operating in Jakarta since 1875. This is significant because animal markets bring together a panoply of species from diverse geographic areas, each with its unique burden of infectious agents.[12] Monkeys, often captured from the wild, are kept in close proximity with domesticated and other wild

* Address correspondence to Lisa Jones-Engel, Washington National Primate Research Center, University of Washington, Seattle, WA 98195. E-mail: jonesengel@bart.rprc.washington.edu

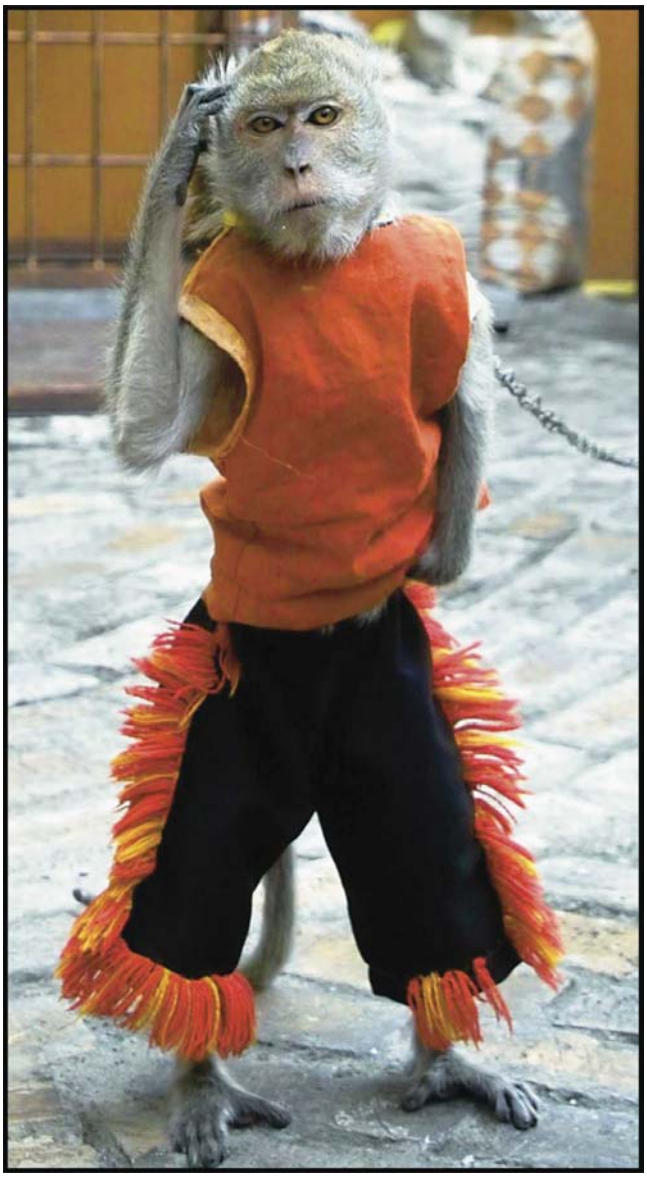

FIGURE 1. Performing monkeys (*M. fascicularis*) from Jakarta, Indonesia, are appealing. Photo taken by Phil and Fransiska Brain. This figure appears in color at www.ajtmh.org.

animals such as Asian bears, reptiles, bats, civets, dogs, cats, and numerous avian species. Animals in markets such as Pramuka are typically kept in small, crowded cages with poor airflow and waste disposal, conditions that increase the likelihood of pathogen transmission. These conditions are also likely to stress the animals, depressing immune function and increasing their vulnerability to infection.[12–15]

In an effort to characterize the performance monkey niche as it relates to the bidirectional transmission of infectious agents, previously we described the seroprevalence of several enzootic simian viruses in a population of performing monkeys from Jakarta, Indonesia.[5] A fuller picture of that bidirectional pathogen transmission is presented here as we characterize the exposure of this same population of performing monkeys to several endemic human viruses that are typically transmitted through the respiratory tract.

MATERIALS AND METHODS

Serum was collected from 19 performing monkeys (*M. fascicularis*) from Kampung Dukuh, a village in East Jakarta, Indonesia, as previously described.[5] Kampung Dukuh is known as a community where owners of performing monkeys are concentrated. Table 1 presents the results of ELISA screening for exposure to select human respiratory pathogens, including measles, influenza A and B, parainfluenza 1, 2, and 3, mumps, rubella, and respiratory syncytial virus in these monkeys.

RESULTS

Twelve of 19 animals (68.4%) exhibited serological evidence of exposure to at least one human respiratory pathogen. Five of 10 animals had antibodies to more than one pathogen. Nine of 19 animals (47.4%) had antibodies to measles. In a sub-sample of 10 animals, 5 had a positive rubella assay, 1 had a positive parainfluenza 2 assay, and 4 had a positive assay for parainfluenza 3. None of the animals were antibody positive to parainfluenza 1, mumps, influenza A, influenza B, or respiratory syncytial virus.

DISCUSSION

Mack and Noble[16] were the first to document transmission of a virus from humans to performing monkeys. Their report focuses on the significance of smallpox infection in a small population of performing monkeys in Pakistan. The authors conclude that, for smallpox at least, human-to-NHP pathogen transmission is "an ecological curiosity." Here we emphasize how our results speak to the general question of inter-species transmission of respiratory pathogens between humans and performing monkeys. Our data suggest that, among these 19 performing monkeys, at least 12 instances of human-to-NHP transmission occurred. Only a minority of performance monkeys (41.2%) did not become infected by a human respiratory pathogen. It is not unreasonable to assume that the kinds of interspecies interaction that allow transmission from humans to NHPs (i.e., close physical contact leading to exchange of respiratory pathogens) may also allow transmission of zoonotic respiratory viruses borne by NHPs to humans. While it is unlikely that these NHPs harbor enzootic respiratory viruses of primate origin that are pathogenic to humans, we suggest that NHPs in markets may become infected by respiratory pathogens present in any number of different species with which they come into contact. Whereas few humans outside of dealers in the markets themselves invite the possibility of close contact with a bat or civet, monkeys are an appealing companion and thus make for a playful conduit for respiratory pathogens in other species to jump to humans (Figure 1).

The aspect of the performance monkey "niche" that presents the greatest public health threat is the potential that these monkeys may act as a conduit for infectious agents passing between market animals and human populations. It should also be noted that the capture of wild NHPs for the animal trade is a significant issue for NHPs conservation both as a result of mortality associated with capturing and the subsequent morbidity and mortality among NHPs that are exposed to endemic human pathogens such as measles, influenza, tuberculosis.[12] Local, provincial, and federal govern-

TABLE 1
Sample information and results of ELISA* tests

ID	Sex	Age†	Weight (kg)	Measles	Rubella	Parainfluenza 1	Parainfluenza 2
TK16	F	2	1.5	Negative			
TK17	F	2	1.2	Negative			
TK18	F	4	3.0	**React**	**React**	Negative	Negative
TK19	M	2	1.8	Negative	**React**	Negative	Negative
TK20	F	3	2.5	**React**	Negative	Negative	**React**
TK21	F	3	2.2	**React**			
TK22	M	2	1.0	**React**			
TK23	M	2	1.7	**React**	Negative	Negative	Negative
TK25	F	3	2.0	**React**			
TK28	F	2	2.0	Negative	**React**	Negative	**React**
TK29	M	2	1.2	Negative			
TK31	M	3	3.5	Negative			
TK32	F	1	1.0	Negative	**React**	Negative	Negative
TK33	F	3	3.0	Negative	Negative	Negative	Negative
TK35	M	2	3.0	**React**	Negative	Negative	**React**
TK36	F	2	1.8	Negative			
TK37	M	4	4.5	**React**	**React**	**React**	**React**
TK38	M	4	3.8	**React**	Negative	Negative	Negative
TK39	F	3	2.7	Negative	Negative	Negative	Negative
Total percent positive				**47.4%**	**45.5%**	**9.1%**	**36.4%**

* ELISAs (IgG) were initially performed at WaNPRC using a commercial ELISA kits (IBL ImmunoBiological Laboratories, Hamburg, Germany). Confirmatory testing on the same samples was performed at Esoterix Simian Diagnostic Laboratory in San Antonio, TX.
† Age class based on observed dental eruption pattern: 1, infant; 2, juvenile; 3, subadult; 4, adult.

ments should take all steps necessary to ensure that NHPs are not sold at animal markets. In addition, the local population and tourists should be made aware of the potential risks for *bi-directional* pathogen exposure associated with direct contact with performance monkeys or other captive NHPs. Given the recent data on infectious diseases experienced by international tourists and others returning to North America and Europe, zoonotic transmission in Asia has potentially global implications.[17]

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Authors' addresses: Michael A. Schillaci, Department of Social Sciences, University of Toronto at Scarborough, 1265 Military Trail, Scarborough, Ontario, Canada M1C 1A4, Telephone: 416-287-7328, Fax: 416-287-7283, E-mail: schillaci@utsc.utoronto.ca. Lisa Jones-Engel, Washington National Primate Research Center, University of Washington, Seattle, WA 98195, Telephone: 206-221-6843, Fax: 206-543-7959, E-mail: jonesengel@bart.rprc.washington.edu. Gregory A. Engel, Swedish/Providence Family Medicine Residency, Seattle, WA 98122, Telephone: 206-320-2235, Fax: 206-543-7959, E-mail: Gregory.Engel@swedish.org. Randall C. Kyes, Washington National Primate Research Center, University of Washington, Seattle, WA 98195, Telephone: 206-543-3025, Fax: 206-543-7959, E-mail: rkyes@u.washington.edu.

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