Published in final edited form as:

Am J Primatol. 2012 June ; 74(6): 543–550. doi:10.1002/ajp.20988.

PRIMATES AND PRIMATOLOGISTS: SOCIAL CONTEXTS FOR INTERSPECIES PATHOGEN TRANSMISSION

GA Engel¹ and L Jones-Engel^{2,*}

¹Swedish/ Cherry Hill Family Medicine Residency and Washington National Primate Center, Seattle, Washington, USA

²Washington National Primate Center, Seattle, Washington, USA

Abstract

Humans and nonhuman primates (NHP) interact in a variety of contexts. The frequency, duration and intensity of interspecies interaction influence the likelihood that contact results in cross-species transmission of infectious agents. Here we present results of a cross-sectional survey of attendees at a national conference of primatologists, characterizing their occupational exposures to NHP. Of 116 individuals who participated in the study, 68.1% reported having worked with NHP in a field setting, 68.1% in a laboratory setting and 24.1% at a zoo or animal sanctuary. Most subjects (N=98, 84.5%) reported having worked with multiple NHP taxa, including 46 (39.7%) who had worked with more than 5 distinct taxa. Sixty-nine subjects (59.5%) recalled having been scratched by a NHP and 48 (41.1%) had been bitten; 32 subjects reporting being bitten more than once. Eleven subjects (9.5%) reported having been injured by a needle containing NHP tissue or body fluids. We conclude that primatologists are at high risk for exposure to NHP-borne infectious agents. Furthermore, primatologists' varied occupational activities often bring them into contact with multiple NHP species in diverse contexts and geographic areas, over extended periods of time, making them a unique population with respect to zoonotic and anthroponotic disease risk.

Keywords

Nonhuman primate; primatologist; cross-species disease transmission; field research; disease risk; laboratory primates

Introduction

Most infectious diseases that affect humans are introduced, at some point, from an animal reservoir, with nonhuman primates (NHP) among the most important reservoirs [Daszak et al., 2000; Taylor et al., 2001; Woolhouse and Gowtage-Sequeria, 2005]. As a result, transmission of infectious agents from NHP to humans has been the object of both scientific research as well as intense interest in the lay community. People exposed to NHP in occupational settings, such as laboratory workers, zoo staff and field researchers are, in a real sense, on the front lines of global efforts to identify, characterize and prevent newly emerging diseases. Indeed, the specter of dreaded, albeit rare, diseases such as Ebola hemorrhagic fever and Herpes B (*Macacine herpesvirus 1*) meningoencephalitis has led to increased concern for the safety of people who work with and around NHP and to expanded

*Corresponding Author, Lisa Jones-Engel, Ph.D., WANPRC – HBS I-039, 1705 NE Pacific St, Seattle, WA 98195, jonesengel@wanprc.org, 206/221-6843.

protocols for preventing infection with enzootic NHP-borne infectious agents in occupational settings[Artenstein et al., 1991;Cohen et al., 2002;Davenport et al., 1994;Jones et al., 2008;MMWR, 1996;Roberts and Andrews, 2008].

Past research on cross-species contact and infectious agent transmission

Workers at laboratories and zoos were among the first to be systematically tested for evidence of infection with enzootic NHP-borne viruses [see Murphy et al., 2006 for review]. Concern about Herpes B infection prompted a serosurvey of 166 workers at a primate research lab, but failed to find serologic evidence of infection[Freifeld et al., 1995]. In contrast, cross-sectional studies of zoo and primate lab workers found evidence of asymptomatic infection with three simian retroviruses: simian foamy virus (SFV) [Sandstrom et al., 2000; Switzer et al., 2004] and simian retrovirus (SRV) [Lerche et al., 2001] and simian immunodeficiency virus (SIV)[Khabbaz et al., 1992]. Subsequent research has provided evidence of transmission of some of these simian retroviruses in areas of the world where naturally occurring populations of NHP come into contact with local human populations, including SFV from several species of macaques to people in other contexts, including workers at monkey temples and villagers in South and Southeast Asia[Jones-Engel et al., 2005;Jones-Engel et al., 2008]. Hunters and consumers of NHP bushmeat in Central Africa have also been shown to be infected with simian retroviruses acquired from chimps, gorillas and monkeys [(Calattini et al., 2007;Wolfe et al., 2004;Wolfe et al., 2005].

A limited number of published papers have addressed exposures to NHP in other settings. The GeoSentinel Surveillance Network, which gathered systematic data on illnesses in returning travelers between 1998–2005, identified 320 cases of animal-related injuries, including 59 caused by monkeys, among over 23,000 travelers who sought medical care after a journey[Gautret et al., 2007]. Relatively little is known about exposures to NHP among pet owners[Chomel et al., 2007;Jones-Engel et al., 2001], though estimates of the number of NHP kept in the United States alone run to 15,000. One small study did not find serologic evidence of infection with Herpes B in 24 humans exposed to pet macaques[Ostrowski et al., 1998].

Analyzing the risk of cross-species transmission between primatologists and NHP

Whether or not infectious agents are transmitted between NHP and humans likely depends on numerous factors, including frequency and duration of interspecies contact as well as specific NHP and human behaviors. A risk analysis framework can help to estimate the risk of cross-species transmission using mathematical models that incorporate complex, interrelating variables, taking into account uncertainties in the values of individual variables and their impact [Travis et al., 2006; Engel et al., 2006] on risk estimates. The utility of these models depends to a great extent on the accuracy of the data that informs the model. To date, most of the research on cross species transmission has focused on *what* is being transmitted, leaving largely unaddressed the question of *how* transmission occurs. Thus, a fuller understanding of the epidemiology and epizootiology of interspecies contact, with an increased appreciation of the ways in which humans and NHP interrelate offers the possibility of building more robust risk analysis models. These models, in turn, can identify “hot spots” where transmission is most likely to occur and may afford insights into strategies aimed at preventing zoonotic and anthroponozoonotic diseases[Cascio et al., 2011;Woolhouse, 2008].

Objectives of the present study

Attendees at American Society of Primatology (ASP) meetings constitute a unique group whose commonality is that their work, or avocational interest, concerns primates, most often NHP. Beyond this basic fact, however, the specifics of their encounters with NHP are quite

varied. The present research seeks to characterize this group, especially with respect to activities and experiences that present a risk of infection with NHP-borne infectious agents. We have divided NHP-related activities into three major categories: lab-based, field-based and zoo or sanctuary-based. Our objective is to focus on activities that may have particular relevance to emerging infectious diseases.

Methods

Setting and Sampling

The analyses and results of this cross-sectional survey are based on data collected from subjects recruited for participation in this study at the 2009 conference of the American Society of Primatologists (ASP), held in San Diego, USA September 18–21, 2009. Three hundred and eighty individuals attended the conference (K. Phillips, personal communication). The authors have been conducting research on cross-species infectious agent transmission for the past decade. The human subjects' research protocols have been reviewed and approved by the University of Washington Institutional Review Board (23055). This research adhered to the American Society of Primatologists (ASP) Principles for the Ethical Treatment of Non Human Primates.

Procedures and measures

ASP officers made conference attendees aware of the research and an area adjacent to meeting auditoriums was designated for research activities. The authors were available in this area several hours a day during the conference. Subjects could approach the authors and ask questions about the study. If the subject chose to participate in the research they were given an informed consent to read and sign. After consenting to the research they were asked to fill out a questionnaire. Upon completion of the questionnaire, blood, cheek swab and nasal swab samples were collected (currently being analyzed for human and NHP-borne infectious agents as part of related research). Data were analyzed using SAS JMP-9 (Cary, IN, USA).

Sociodemographic and exposure data

Sociodemographic data including age, sex, marital status and number of children as well as occupational information describing the location, type and duration of all employments relating to NHP were collected. Additionally, subjects were asked to list and describe all occupational exposures to NHP and/or NHP tissues and body fluids, specifying the activity with which they were engaged with at the time of exposure, any medical treatment they received as well as any health sequelae of exposure.

Definitions

Subjects were considered to have “worked with” a species if work activities entailed physical proximity to NHP or their tissues. We defined “high-risk exposures” as bites, scratches, needle injuries and mucosal (oral, nasal and ocular mucous membrane) contact with NHP tissue or body fluids. Field work was defined as any activity which involved observing or collecting biological specimens from free ranging NHP. Captive primates were defined as those in laboratories, zoos, and sanctuaries.

Results

Demographic profile

Of the 380 individuals eligible for participation, 116 participated as subjects in this study, a participation rate of 30.5%. Figure 1 summarizes subjects' demographic and occupational

data. The average age of subjects was 41.3 yrs (s.d. 14.1). Over two-thirds (67.2% N=78) were female. Eighty-four (72.4%) subjects identified their current occupational setting as academic, eighteen (15.5%) currently worked in a laboratory, five (4.3%) worked at a zoo and the remaining nine were either retired or worked in a variety of other settings.

NHP taxa

Overall, subjects reported having worked with 64 species of NHP. Sixty nine (59.5%) had worked with New World monkeys, 55(47.4%) had worked with African Old World monkeys, 67 (57.8%) had worked with Asian Old World monkeys, 40 (34.5%) had worked with African apes and 22(19.0%) had worked with Asian apes or lesser apes. Twenty one subjects (18.1%) reported having worked with prosimians. Forty six subjects (39.7%) had worked with more than 5 distinct taxa. Fifty-seven subjects (49.1%) had worked with both Old World and New World primates. No statistical differences were observed (Chi square >0.05) between male and female subjects with respect to the groups of NHP with which they had worked (NWM, OWM, apes).

Context of primatological work

Most subjects (76.3% of the men and 83.3% of the women) reported having worked with captive NHP at some point during their careers. Seventy-nine subjects (68.1%) reported having worked with NHP in a laboratory context. Seventy-nine subjects (68.1%) reported that they had worked with NHP in the field. Nearly a quarter of the respondents (N= 28, 24.1%) reported having worked with NHP at a zoo or animal sanctuary. Almost half of all subjects (49.1%) had, at one point, worked with NHP in the field, and, at another point in their career, worked with NHP in the laboratory. A similar percentage of men (63.2%) and women (66.7%) reported having worked with NHP in a field context.

Work locations

Collectively, the 79 ASP members who reported having worked with NHP in the field listed sites in a total of 44 countries on five continents (See Figure 2). The subjects who reported working in laboratory settings listed sites in 27 states in the USA, in addition to sites in Puerto Rico and four foreign countries (Figure 3). Subjects reported working at zoos and sanctuaries in 14 states in the U.S. Fifty-one of 79 subjects who did field work reported having worked with NHP in more than one country. Forty-six of these had worked with NHPs on more than one continent.

Behaviors related to contact with NHP

There was no significant difference between the sexes for individuals who reported contact with NHP: 85 subjects (73.3%) reported that they had given food to an NHP and 97 (85.1%) reported having touched an NHP during the course of their career ($\chi^2=0.141$). Twelve individuals (10.4%) had owned a pet NHP and five (4.3%) reported that they had eaten NHP meat.

High risk exposures

Table 1 provides data on the types of high risk exposures reported by the subjects. Contact with NHP body fluids (urine, feces, saliva or blood) was the most commonly reported exposure with 83 (71.6%) subjects noting that they had been splashed. Sixty-nine subjects (59.5%) recalled having been scratched by an NHP and 48 (41.1%) who had been bitten; 32 subjects had been bitten more than once. Eleven (9.5%) reported having been injured by a needle bearing NHP tissue or body fluids. Of the seventy-eight (67.2%) subjects who reported a bite, scratch, or needle stick injury, 54 reported the exposure happened in a

laboratory, 27 in the field, 12 at a zoo or animal sanctuary, and one subject reported an injury from a pet NHP.

A similar percentage of male (65.8%) and female (66.7%) subjects had been either bitten or scratched by a NHP. A greater percentage of male subjects (50.0%) than female subjects (37.2%) reported having been bitten by a NHP, but this difference did not reach statistical significance ($\chi^2 = 1.720$; $p < 0.1896$). There is a significant statistical difference between ever being bitten or not bitten by age class, with younger subjects being less likely to have been bitten ($\chi^2 = 9.956$; $p < 0.0412$).

Subjects recalled a total of 115 separate high risk exposures in occupational settings. Of these, 49 (42.6%) occurred while the subject was engaged in husbandry activities (such as transporting and feeding animals), 39 (33.9%) occurred while the subject was performing a medical procedure (such as phlebotomy or parenteral administration of medication) and 27 (23.5%) occurred during field work.

Of the 48 subjects reporting a bite, the species most often involved were rhesus macaques (n=11), pigtailed macaques (n=6), marmosets, (n=5) long-tailed macaques (n=5) and capuchins (n=5). Thirty-three (28.4%) subjects reported a bite, scratch or needle injury from more than one NHP species. Nineteen (16.4%) individuals reported being injured in more than one geographic location.

Of the 49 subjects who worked with rhesus macaques, 24 (49.0%) reported having been bitten or scratched, compared to 7 out of 27 (25.9%) who had worked with long-tailed macaques and 5 of 25 (20.0%) who had worked with capuchins. Of the 14 who reported working with pigtailed macaques, 7 (50.0%) reported a bite or scratch. These results do not include the eight subjects who indicated “multiple” or “too numerous to count” injuries, but failed to specify the species of NHP involved.

Care for bites, scratches and needle injuries

Fifty-four of those bitten or scratched reported that the wound bled and 21 noted that the injury healed with a scar. Of the 74 reported injuries that bled, 44 (59.5%) occurred in the laboratory setting, 17 (23.0%) occurred at a zoo and 13 (17.6%) occurred in the field. Sixteen individuals received care from a healthcare provider; one was hospitalized. Seven subjects remembered specifically having taken antiviral medications. These figures do not include the eight subjects who reported being bitten or scratched on multiple occasions, but failed to include information on wound care or sequelae of their injury.

Discussion

Zoonotic transmission is thought to be the most common means by which infectious agents are introduced into human populations [Woolhouse, 2008]. It has been observed that, compared to other animal reservoirs, a disproportionately high percentage of infectious diseases that affect human populations originated from NHP [Wolfe et al., 2007]. A possible explanation for this observation is that the genetic, physiologic and behavioral similarities between humans and our closest phylogenetic relatives contribute to making us susceptible to similar pathogens.

Primatologists and cross-species transmission

New patterns of human disease can arise when the relationship between animal reservoirs and human populations change, resulting in increased, or more intensive contact [Cascio et al., 2011; Woolhouse and Gaunt, 2007]. Contact provides an opportunity for infectious agents endemic/enzootic in a host population to infect individuals in a population that

previously was uninfected. This phenomenon, known as host switching, is thought to have occurred recently during an outbreak of adenovirus in a colony of Titi monkeys at a primate laboratory, where a researcher developed symptomatic adenoviral infection, though the direction of transmission in this case is still unresolved [Chen et al., 2011]. Similarly, an increase in the number of human infections with *Plasmodia knowlesi*, a malarial parasite enzootic in macaques, has been associated with increased contact between humans and macaques in Asia [Lee et al., 2011]. Another mechanism for emerging infectious disease is change of the infectious agent itself, such as when two distinct agents recombine to form a new infectious agent with novel properties, leading to increased pathogenicity, infectivity or transmissibility to and/or among human hosts. Recombination is thought to have been a critical factor in the emergence of HIV as a human pathogen [Bailes et al., 2003].

Seen in this context, the results presented above suggest that primatologists have the potential to play a unique role in the genesis and/or transmission of emerging zoonotic, as well as anthroponozoonotic diseases. Most of the primatologists we queried travelled between geographically distant areas, coming into contact with diverse populations of humans and NHP, raising the prospect of host switches. Many subjects had worked with free-ranging NHP at one time and captive animals at another. Moving between human and NHP populations separated by distance or by man-made barriers, primatologists have the capacity to link reservoirs of infectious agents with potential hosts that, otherwise, would not come together. Furthermore, their activities often bring them into close contact with NHP, increasing the risk of exposure to NHP tissues and fluids that contain enzootic pathogens and consequently increasing the likelihood of cross species transmission. While other groups (i.e. lab workers, bushmeat hunters, NHP pet owners) also have close contact with NHP over extended periods of time, or even contact with geographically removed populations of NHP (e.g. ecotourists), primatologists as a group combine these two aspects of cross-species contact to a greater extent. Thus, primatologists are potential conduits for pathogens that otherwise would require multiple transmissions/transmigrations in order to pass from pathogen reservoirs to distant host populations. As a corollary, individual primatologists who may be at greatest risk, from a zoonotic and anthroponozoonotic standpoint, are those who have the most intensive contact over the most total time, with the most NHP populations in the greatest number of locations/contexts.

In addition to their potential roles in promoting/facilitating host switches, primatologists, by virtue of their repeated and often intensive exposure to multiple pathogens over extended periods of time could play a role as ‘mixing vessels’ for genetic recombination of pathogens. The analogy here is to HIV, which is hypothesized to have originated through recombination of SIVs from guenons and sooty mangabeys, with the “mixing vessel” being a chimpanzee. Our data suggest that, in the course of a career, it is not unusual for a primatologist to work with multiple populations, or multiple species of NHP, increasing the chances for novel combinations of infectious agents to infect an individual, thereby increasing the potential of microbial recombination.

Part of what makes primatologists an appropriate focus for research on cross-species infectious agent is their patterns of contact with NHP. Many of the primatologists we surveyed reported having intensive contact with NHP over extended periods of time. Certain activities may be assumed to carry higher risk of infectious agent transmission, particularly those that involve contact with blood or body fluids and the high likelihood of breaching the skin barrier (as may occur with bites/scratches/needle sticks) as well as likelihood of transmission of respiratory pathogens especially those that entail long periods of close face-to-face proximity. It is likely that risk of transmission accumulates over time; though perhaps not in a linear fashion (it is possible that years of experience may have a protective effect, or paradoxically, a nonprotective effect as “veterans” may be less cautious than

neophytes in the way that they handle and interact with the animals). To a great extent, zoonotic and anthroozoonotic risk is inherent in the activities undertaken by primatologists. Our data suggest that work involving husbandry and medical procedures poses the greatest risk for bites and needle sticks respectively, exposures most likely to introduce pathogens by a parenteral route. In contrast, pathogens that are transmitted through the respiratory route (e.g. tuberculosis, influenza, measles) are more likely to be transmitted when primatologists are performing observational research or husbandry activities at a “conversational distance” from their NHP research subjects. Oral/fecal transmission can occur in several contexts, including observational field studies. It should be noted that awareness of zoonotic diseases has increased over the past decades, changing the way primatologists work, and likely modifying the risk of cross-species transmission. In the mid 20th century relatively little attention was paid to the potential risks of zoonotic and anthroozoonotic disease. However, cases of severe zoonotic disease, including infections with *Macacine herpesvirus 1* (Herpes B) and Marburg-Reston virus, led to the implementation of stricter guidelines governing contact with NHP [B Virus Working Group, 1988; Holmes et al., 1995; Roberts and Andrews, 2008]. In the field, concern about human-to-NHP disease transmission has led researchers to modify protocols for observational research, including specific recommendations for observational distances, use of masks for researchers with respiratory infections, and waste disposal [Epstein and Price, 2009; Wallis, 2000]. It is likely that these changes in occupational practices have had some impact on the risk of zoonotic and anthroozoonotic disease transmission.

The social relationships between humans and NHP are likely an important aspect of human-NHP interaction that the above data touch upon tangentially but do not address directly. Primatologists approach their subject matter from a broad range of perspectives, temperamental dispositions and personality styles. But, there is little systematic research on how this may impact transmission of infectious agents. For example, how do primatologists’ attitudes toward NHP influence contact and the risk of zoonotic and anthroozoonotic transmission? Are primatologists who are drawn to interacting with NHP more likely to become infected, or infect their study animals? And, if so, is this observed across all contexts of human/NHP interaction? Further data in these areas are needed to build robust risk analysis models that can increase our understanding of how attitudes and behavior influence disease risk.

Limitations

Our conclusions are subject to several limitations. Though a substantial proportion of the eligible population did participate in the study, recruitment was voluntary, not randomized, raising the possibility of selection bias. Subjects were asked to provide data relating to events that occurred over periods of time, sometimes several decades, raising the possibility of recall bias. Insufficient numbers of subjects in some subcategories could potentially obscure statistically significant associations. Future research in this area could address these issues using a prospective design, allowing the calculation of exposure rates and risks.

Acknowledgments

The authors are grateful to our Society of American Primatologists members and Executive Committee for supporting and participating in this research. We thank Gunwha Oh for her outstanding figures showing the global distribution of primatologist and their sites and Regina Liszanckie for editorial assistance and data entry. We thank the AJP editors and our reviewers for their diligence and insightful comments. We sincerely appreciate the opportunity that John Capitanio gave us when he invited us to participate in the 2010 ASP Interdisciplinary Symposium on “Social Processes and Disease in Nonhuman Primates”. This research is funded by NIH-NCRR grant P51 RR000166 and NIH-NIAID grant R01 AI078229.

References

- Artenstein AW, Hicks CB, Goodwin BS Jr, Hilliard JK. Human infection with B virus following a needlestick injury. *Review of Infectious Diseases*. 1991; 13:288–291.
- B Virus Working Group. Guidelines for prevention of Herpesvirus simiae (B virus) infection in monkey handlers. *Journal of Medical Primatology*. 1988; 17:77–83. [PubMed: 2843643]
- Bailes E, Gao F, Bibollet-Ruche F, Courgnaud V, Peeters M, Marx PA, Hahn BH, Sharp PM. Hybrid origin of SIV in chimpanzees. *Science*. 2003; 300:1713. [PubMed: 12805540]
- Calattini S, Betsem EBA, Froment A, Mauclore P, Tortevoe P, Schmitt C, Njouom R, Saib A, Gessain A. Simian foamy virus transmission from apes to humans, rural Cameroon. *Emerging Infectious Diseases*. 2007; 13:1314–1320. [PubMed: 18252101]
- Cascio A, Bosilkovski M, Rodriguez-Morales AJ, Pappas G. The socio-ecology of zoonotic infections. *Clinical Microbiology and Infection*. 2011; 17:336–342. [PubMed: 21175957]
- Chen EC, Yagi S, Kelly KR, Mendoza SP, Maninger N, et al. Cross-Species Transmission of a Novel Adenovirus Associated with a Fulminant Pneumonia Outbreak in a New World Monkey Colony. *PLoS Pathog*. 2011; 7(7) e1002155. doi:10.1371/journal.ppat.1002155.
- Chomel BB, Belotto A, Meslin FX. Wildlife, exotic pets, and emerging zoonoses. *Emerging Infectious Diseases*. 2007; 13:6–11. [PubMed: 17370509]
- Cohen JI, Davenport DS, Stewart JA, Deitchman S, Hilliard JK, Chapman LE. Recommendations for prevention of and therapy for exposure to B virus (cercopithecine herpesvirus 1). *Clinical Infectious Diseases*. 2002; 35:1191–1203. [PubMed: 12410479]
- Daszak P, Cunningham AA, Hyatt AD. Emerging infectious diseases of wildlife--threats to biodiversity and human health. *Science*. 2000; 287:443–449. [PubMed: 10642539]
- Davenport DS, Johnson DR, Holmes GP, Jewett DA, Ross SC, Hilliard JK. Diagnosis and management of human B virus (Herpesvirus simiae) infections in Michigan. *Clinical Infectious Diseases*. 1994; 19:33–41. [PubMed: 7948555]
- Engel G, Hungerford LL, Jones-Engel L, Travis D, Eberle R, Fuentes A, Grant R, Kyes R, Schillaci M. Risk assessment: A model for predicting cross-species transmission of simian foamy virus from macaques (*M. fascicularis*) to humans at a monkey temple in Bali, Indonesia. *American Journal of Primatology*. 2006; 68:934–948. [PubMed: 16900504]
- Epstein JH, Price JT. The Significant but Understudied Impact of Pathogen Transmission from Humans to Animals. *Mount Sinai Journal of Medicine*. 2009; 76:448–455. [PubMed: 19787650]
- Freifeld AG, Hilliard J, Southers J, Murray M, Savarese B, Schmitt JM, Straus SE. A controlled seroprevalence survey of primate handlers for evidence of asymptomatic herpes B virus infection. *Journal of Infectious Disease*. 1995; 171:1031–1034.
- Gautret P, Schwartz E, Shaw M, Soula G, Gazin P, Delmont J, Parola P, Soavi MJ, Matchett E, Brown G, Torresi J. Animal-associated injuries and related diseases among returned travellers: A review of the GeoSentinel Surveillance Network. *Vaccine*. 2007; 25:2656–2663. [PubMed: 17234310]
- Holmes GP, Chapman LE, Stewart JA, Straus SE, Hilliard JK, Davenport DS. Guidelines for the prevention and treatment of B-virus infections in exposed persons. The B virus Working Group. *Clinical Infectious Disease*. 1995; 20:421–439.
- Jones KE, Patel NG, Levy MA, Storeygard A, Balk D, Gittleman JL, Daszak P. Global trends in emerging infectious diseases. *Nature*. 2008; 451:990–993. [PubMed: 18288193]
- Jones-Engel L, Engel GA, Schillaci MA, Babo R, Froehlich J. Detection of antibodies to selected human pathogens among wild and pet macaques (*Macaca tonkeana*) in Sulawesi, Indonesia. *American Journal of Primatology*. 2001; 54:171–178. [PubMed: 11443632]
- Jones-Engel L, Engel GA, Schillaci MA, Rompis A, Putra A, Suaryana KG, Fuentes A, Beer B, Hicks S, White R, Wilson B, Allan JS. Primate-to-human retroviral transmission in Asia. *Emerging Infectious Diseases*. 2005; 11:1028–1035. [PubMed: 16022776]
- Jones-Engel L, May CC, Engel GA, Steinkraus KA, Schillaci MA, Fuentes A, Rompis A, Chalise MK, Aggimarangsee N, Feeroz MM, Grant R, Allan JS, Putra A, Wandia IN, Watanabe R, Kuller L, Thongsawat S, Chaiwarith R, Kyes RC, Linial ML. Diverse contexts of zoonotic transmission of simian foamy viruses in Asia. *Emerging Infectious Diseases*. 2008; 14:1200–1208. [PubMed: 18680642]

- Khabbaz RF, Rowe T, Murphey-Corb M, Heneine WM, Schable CA, George JR, Pau CP, Parekh BS, Lairmore MD, Curran JW, Kaplan JE, Schochetman G, Folks TM. Simian Immunodeficiency Virus Needlestick Accident in A Laboratory Worker. *Lancet*. 1992; 340:271–273. [PubMed: 1353193]
- Lee KS, Divis PC, Zakaria SK, Matusop A, Julin RA, Conway DJ, Cox-Singh J, Singh B. Plasmodium knowlesi: reservoir hosts and tracking the emergence in humans and macaques. *PLoS Pathogen*. 2011; 7:e1002015.
- Lerche NW, Switzer WM, Yee JL, Shanmugam V, Rosenthal AN, Chapman LE, Folks TM, Heneine W. Evidence of infection with simian type D retrovirus in persons occupationally exposed to nonhuman primates. *Journal of Virology*. 2001; 75:1783–1789. [PubMed: 11160676]
- Murphy HW, Miller M, Rarner J, Travis D, Barbiers R, Wolfe N, Switzer WM. Implications of simian retroviruses for captive primate population management and the occupational safety of primate handlers. *Journal of Zoo and Wildlife Medicine*. 2006; 37(3):219–233. [PubMed: 17319119]
- MMWR. Ebola-Reston virus infection among quarantined nonhuman primates--Texas, 1996. *MMWR Morbidity and Mortality Weekly Report*. 1996; 45:314–316. [PubMed: 8602131]
- Ostrowski SR, Leslie MJ, Parrott T, Abelt S, Piercy PE. B-virus from pet macaque monkeys: an emerging threat in the United States? *Emerging Infectious Diseases*. 1998; 4:117–121. [PubMed: 9452406]
- Roberts JA, Andrews K. Nonhuman primate quarantine: its evolution and practice. *Institute for laboratory Animal Research Journal*. 2008; 49:145–156.
- Sandstrom PA, Phan KO, Switzer WM, Fredeking T, Chapman L, Heneine W, Folks TM. Simian foamy virus infection among zoo keepers. *Lancet*. 2000; 355:551–552. [PubMed: 10683011]
- Switzer WM, Bhullar V, Shanmugam V, Cong ME, Parekh B, Lerche NW, Yee JL, Ely JJ, Boneva R, Chapman LE, Folks TM, Heneine W. Frequent simian foamy virus infection in persons occupationally exposed to nonhuman primates. *Journal of Virology*. 2004; 78:2780–2789. [PubMed: 14990698]
- Taylor LH, Latham SM, Woolhouse ME. Risk factors for human disease emergence. *Philosophical Transactions of the Royal Society B: Biological Sciences*. 2001; 356:983–989.
- Travis DA, Hungerford L, Engel GA, Jones-Engel L. Disease risk analysis: A tool for primate conservation planning and decision making. *American Journal of Primatology*. 2006; 68:855–867. [PubMed: 16900501]
- Wallis J. Prevention of disease transmission in primate conservation. *Annals of the New York Academy of Science*. 2000; 916:691–693.
- Wolfe ND, Dunavan CP, Diamond J. Origins of major human infectious diseases. *Nature*. 2007; 447:279–283. [PubMed: 17507975]
- Wolfe ND, Heneine W, Carr JK, Garcia AD, Shanmugam V, Tamoufe U, Torimiro JN, Prosser AT, LeBreton M, Mpoudi-Ngole E, McCutchan FE, Birx DL, Folks TM, Burke DS, Switzer WM. Emergence of unique primate T-lymphotropic viruses among central African bushmeat hunters. *Proceedings of the National Academy of Science*. 2005; 102:7994–7999.
- Wolfe ND, Switzer WM, Carr JK, Bhullar VB, Shanmugam V, Tamoufe U, Prosser AT, Torimiro JN, Wright A, Mpoudi-Ngole E, McCutchan FE, Birx DL, Folks TM, Burke DS, Heneine W. Naturally acquired simian retrovirus infections in central African hunters. *Lancet*. 2004; 363:932–937. [PubMed: 15043960]
- Woolhouse M, Gaunt E. Ecological origins of novel human pathogens. *Critical Reviews in Microbiology*. 2007; 33:231–242. [PubMed: 18033594]
- Woolhouse ME. Epidemiology: emerging diseases go global. *Nature*. 2008; 451:898–899. [PubMed: 18288175]
- Woolhouse ME, Gowtage-Sequeria S. Host range and emerging and re-emerging pathogens. *Emerging Infectious Diseases*. 2005; 11:1842–1847. [PubMed: 16485468]

Figure 1.

Basic demographic data (in orange) as well as the number of subjects who reported working with NHP (in blue) and the contexts in which they worked with NHP (in green).

Figure 2.
Geographic distribution of subjects' field sites.

Figure 3.

Respondents were asked to report where they had worked with captive NHP. In the US, many of the states with National Primate Research Centers showed the greatest number of subjects working with captive NHP. In several states, zoo and/or sanctuary NHP accounted for those individuals who had worked with captive NHP. Some respondents also indicated that they had worked with captive animals in Europe and Japan.

Table 1

High risk exposures and the contexts in which they occurred as reported by ASP members

High Risk Exposures to NHP (%)				
	<i>Needle Stick</i>	<i>Scratched</i>	<i>Bitten</i>	<i>Mucosal Splash</i>
Males	6 (13.2)	23 (60.5)	19 (50.0)	28 (73.7)
Females	5 (7.7)	46 (59.0)	29 (37.2)	55 (70.5)
Total	11 (9.5)	69 (59.5)	48 (41.1)	83 (71.6)
Subjects reporting high risk exposure (%)				
Exposed in Laboratory	54 (69.2)			
Exposed in Field	27 (34.6)			
Exposed in Zoo/Sanctuary	12 (15.4)			
Exposed by a Pet	1 (1.3)			