Outbreak of Yellow Fever among Nonhuman Primates, Espirito Santo, Brazil, 2017

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In January 2017, an outbreak involving deaths of humans and New World nonhuman primates (hereafter nonhuman primates [NHPs]) spread from Minas Gerais state to Espirito Santo state. Espirito Santo is located in a forest along the Atlantic coast of southeastern Brazil and borders Minas Gerais, Rio de Janeiro, and Bahia states. The virus advanced through Atlantic forest fragments (7), areas previously considered not at risk for yellow fever virus transmission. We performed histopathologic analyses, immunohistochemical analyses (IHC), and PCRs on 22 NHPs that died early in the Espirito Santo outbreak (Figure 1).

Veterinarians trained by health authorities performed standardized necropsies under the yellow fever national surveillance program (8). Of 22 NHPs found dead, 2 were howler monkeys (Alouatta spp.) and 20 were NHPs not further identified. Liver, spleen, kidney, heart, and lung samples were collected and fixed in 10% neutral buffered formalin and processed for routine histopathology and in liquid nitrogen for RNA real-time reverse transcription quantitative PCR.

Histologic examination indicated the following for all animals: zonal bridging (largely midzonal and centrilobular) or massive liver necrosis with Councilman bodies, varying degrees of macrovacuolar and microvacuolar steatosis, and pleocellular (mainly lymphohistiocytic) inflammatory infiltrates, accompanied by hemorrhage and hemosiderosis (Figure 2, panels A, B; online Technical Appendix Table 1, https://wwwnc.cdc.gov/EID/article/23/12-0685-Techapp1.pdf). Additional liver lesions were microabscesses (6), endothelial necrosis (5), oval cell hyperplasia (2), massive macrovacuolar steatosis with rare midzonal to random single-cell necrosis (1) (Figure 2, panel C), and fibrin microthrombi in sinusoids (1). Other consistent findings were splenic lymphoid depletion and follicular necrosis/lymphocytolysis (19), acute renal tubular necrosis with protein casts and hemoglobin casts (6), and multisystemic hemorrhage, more prominent in lungs (6).

For IHC, we tested liver tissue sections with an in-house primary polyclonal anti–yellow fever virus antibody (1:40,000, derived from hyperimmune mouse serum); signal amplification was achieved with a HiDef Detection

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HRP Polymer System (Cell Marque/Sigma-Aldrich, Rocklin, CA, USA) and visualization with diaminobenzidine (D-5637; Sigma-Aldrich, St. Louis, MO, USA). We included human and nonhuman primate positive and negative control tissues with omitted first-layer antibody. Tissue from all animals showed positive granular cytoplasmic hepatocyte immunolabeling, with varying percentages of involvement and immunolabeling intensity (online Technical Appendix Table 2). Immunopositivity was more intense in degenerating and remaining hepatocytes, most often encompassing periportal cord segments and terminal plates (Figure 2, panel D). Necrotic hepatocytes consistently lacked immunoreactivity.

For PCRs, we extracted viral RNA from whole blood (n = 6); serum (n = 1); and liver, kidney, and spleen (n = 4) tissue samples by using a QIAamp RNA Blood Mini Kit (QIAGEN, Valencia, CA, USA), following the manufacturer’s instructions. We amplified virus fragment by using the protocol designed by Drosten et al. (9), which targets the 5’ noncoding region (112-bp long) of the genome. All samples were positive; cycle thresholds were 11–26 (cutoff value 38; online Technical Appendix Table 2).

Brazil has an established yellow fever national surveillance program (e.g., postmortem NHP studies, vector analyses) focused on early detection of virus circulation, which enables prompt implementation of vaccination and vector control (8). Yellow fever diagnosis under this program is achieved by histopathologic, IHC, and PCR results from liver samples of NHPs, performed by reference laboratories (e.g., Adolfo Lutz Institute, São Paulo, Brazil). A multidisciplinary work team and combination of laboratory techniques are essential for a quick, high-quality response that initiates field actions (e.g., vaccination, vector control).

We observed classic histopathologic commonalities with yellow fever–associated disease in humans (midzonal lytic necrosis, apoptotic bodies, steatosis, and scarce paucicellular inflammation) (10,11). The severity and extent of these lesions probably accounted for severe hepatic failure and death of the animals. The knowledge of naturally occurring yellow fever–associated disease in NHPs gained since the early 1900s is fragmentary (12) and mainly limited to Alouatta spp. and Callithrix spp. NHPs (6,11). Alouatta spp. monkeys are very susceptible to yellow fever; fatal disease has supported a sentinel role for yellow fever virus circulation since the 1930s (11). Hepatic lesions of several NHP species, experimentally or naturally infected, are similar to those in humans (11). In this study, 1 animal had atypical liver histopathologic features, characterized by massive steatosis with rare midzonal to random single-cell necrosis/apoptosis. Additional liver findings were multifocal microabscesses, probably the result of acute bacterial ascending (intestinal) infection or concomitant septicemia; endothelial necrosis; and attempted hepatic regeneration as suggested by oval cell hyperplasia. The pathologic signature of yellow fever–associated disease in NHPs (≈150 species) is not fully resolved. Ongoing comparisons between yellow fever–associated disease in humans and NHPs may help elucidate convergent and divergent pathogenetic mechanisms and characterize typical and atypical features, thus delineating the pathologic signature in NHPs.

Before the advent of PCR, the method of choice for diagnosing yellow fever was IHC, which remains a highly reliable diagnostic tool (13), even in the presence of some autolysis (14). In our study and the ongoing outbreak, histopathologic analyses and IHC were vital for successful diagnosis, enabling detection of atypical presentation, paralleling the sensitivity and specificity of PCRs. In a public health context, IHC will greatly aid in yellow fever diagnosis when molecular analysis is not an option, as occurred for 11 of 22 cases in this study. Although RNA extraction from paraffin-embedded tissues is possible, it is not extensively applied and the degradation of RNA may lead to false-negative results.

Figure 1. Locations (red shading) of nonhuman primates that died of yellow fever, Espirito Santo, Brazil, January 2017. Inset shows location of Espirito Santo (light gray shading) and 4 other states within Brazil: GO, Goias; MG, Minas Gerais; MT, Mato Grosso do Sul; SP, Sao Paulo.
Conclusions
During January–July 2017, yellow fever was diagnosed for 150 of 1,000 tested NHPs (15% occurrence) from southern states of Brazil. NHPs were effective yellow fever sentinels and enabled rapid government response (8,15). Although the Espirito Santo outbreak had damaging socioeconomic and environmental consequences, adequate case conduction and diagnosis may have prevented further human deaths and diminished disease expansion. In contrast, the effects of yellow fever virus spreading among NHPs in the Atlantic forest are expected to be devastating.

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Dr. Fernandes is the leading veterinary pathologist responsible for yellow fever diagnosis in NHPs at the Adolfo Lutz Institute. Her research focuses on wildlife pathology and arbovirus disease mechanisms, specifically in comparative pathology of human and NHP yellow fever–associated disease, and seeks to characterize species-specific pathogenic mechanisms and factorsmodulating yellow fever–endemic cycles and triggering outbreaks among humans and NHPs in the Americas.

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