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gastroenteritis virus (TGEV), to examine the survival and inactivation of coronaviruses on PPE.

TGEV was kindly provided by R. Baric (University of North Carolina–Chapel Hill) and was grown in swine testicular cells. Viruses were propagated by infecting confluent layers of cells in flasks, harvesting cell lysates, centrifuging (at 3000g for 30 min at 4°C), and storing supernatants at –80°C. Viral titers were determined using the most probable number (MPN) assay on confluent cell layers in 24-well plates containing maintenance medium (Eagle’s minimum essential medium, 10% bovine serum replacement; Fetal Clone II [Hyclone]), 10% lactalbumin hydrolysate, and gentamicin–kanamycin [0.1 mg/mL and 0.05 mg/mL, respectively].

Test materials were 1-cm² pieces of contact isolation gowns (MediChoice), latex gloves (Evolution One; Microflex), respirators (N95 1860 Healthcare Particulate Respirator; 3M), hospital scrubs, and nitrile gloves (N-DEX; Best Manufacturing). Viruses in 10 µL of liquid suspension were inoculated onto 3 replicate pieces for each time point and placed at 20°C and 50% ± 3% relative humidity to simulate ambient health-care environment conditions. Time 0 pieces were sampled immediately. At each time point, pieces were removed and eluted by placing them in a 24-well plate with 1 mL of 1.5% beef extract (pH, 7.5) and agitating on a shaking platform (60 rpm) for 20 min. Eluent was diluted in cell culture medium and assayed for infectivity. Virus survival at each time point was expressed as log₁₀ (N_t/N₀), where N_t denotes virus concentration in MPN/mL at time *t* and N₀ denotes initial virus concentration in MPN/mL at time 0.

Coronavirus survival on PPE items varies by material, but infectious virus was detectable on all materials for at least 4 hours (Figure). Only a small amount of infectious virus (0.8

Coronavirus Survival on Healthcare Personal Protective Equipment

Epidemiologic studies of transmission of severe acute respiratory syndrome (SARS) in healthcare environments established a crucial role for personal protective equipment (PPE) in preventing the spread of SARS to healthcare workers.¹ However, viruses can survive on PPE materials,² suggesting that items of PPE may pose a risk of disease transmission if they become contaminated with infectious viruses and if virus transfer to hands occurs during handling. Healthcare workers and patients face emerging risks posed by coronaviruses and human-derived and non-human-derived influenza viruses (eg, novel H1N1 and avian H5N1 viruses) in healthcare settings. Data on the survival of enveloped viruses on PPE is important for assessing risks posed by handling of contaminated PPE and for making decisions regarding extended use or reuse of PPE in outbreak settings. This work was undertaken using a surrogate for SARS coronavirus, transmissible

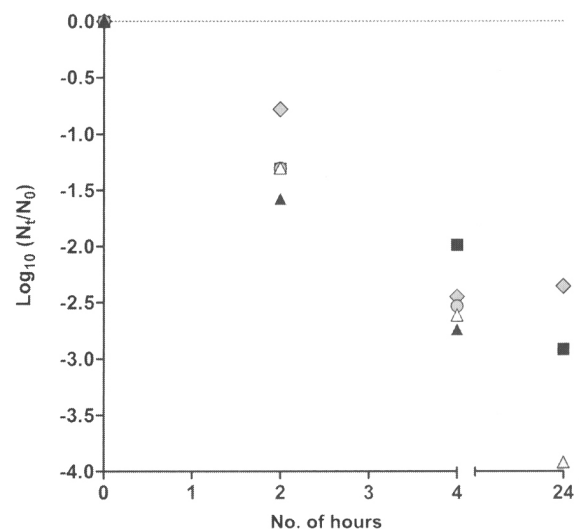


FIGURE Survival of transmissible gastroenteritis virus on personal protective equipment materials. Gray diamonds, N95 mask; white triangles, latex gloves; black triangles, scrub fabric; black squares, contact isolation gown; gray circles, nitrile gloves.

\log_{10}) was lost on an N95 respirator within the first 2 hours, and virus was detectable for up to 24 hours (loss of 3 \log_{10}). On gowns, TGEV was detectable for up to 24 hours, with a 1- \log_{10} decrease over 2 hours and a \sim 3- \log_{10} decrease by 24 hours. Virus was still detectable at 4 hours on scrub fabric. Survival on latex and nitrile gloves was comparable, with a 1.3- \log_{10} decrease by 2 hours and a 2.5- \log_{10} decrease by 4 hours.

Survival experiments using TGEV suggest that infectious coronaviruses can survive on PPE items for the duration of a single patient encounter. This finding is consistent with previous studies of human coronavirus 229E,³ SARS coronavirus,² and influenza A (H1N1) and B,⁴ showing that enveloped viruses can survive for hours on gloves and fabric. Survival of infectious virus on PPE for the length of a patient care encounter creates the potential for viral transfer when PPE is handled after wearing; transfer of infectious viruses from fabric and gloves to hands has been demonstrated,⁵ and experiments with model virus show that virus is transferred to hands and scrubs during the removal of contaminated PPE items.⁶ Viral loads in nasopharyngeal aspirates up to 4.8 \log_{10} polymerase chain reaction copies/mL for influenza⁷ and 6 \log_{10} copies/mL for SARS coronavirus⁸ have been observed, suggesting these viruses could be deposited on PPE during patient care in sufficient numbers that a 0.5–1- \log_{10} decrease during wearing leaves enough infectious virus to pose a risk of transfer during handling. In addition, survival on scrub fabric may pose risks of downstream exposure for house-keeping and laundry staff if used scrubs are laundered in-house. However, dose-response relationships for SARS and influenza are not well understood; additional research is needed to determine the relationship between virus quantity on objects and risk of infection. Survival of viruses on respirators also matters for extended use or reuse of PPE during pandemics. The possibility of PPE shortages during outbreaks of pandemic influenza led the Institute of Medicine to examine the option of using the same N95 respirator for multiple patient encounters. They concluded that “reuse should be considered an option only in circumstances in which adequate supplies simply cannot be obtained,”^{9(p. xiii)} in part because there is no available method for decontaminating a disposable N95 respirator that is harmless to the user, removes the viral threat, and does not compromise the integrity of the respirator. The results of this study suggest that, in the absence of such decontamination, viruses may survive on the respirator for hours, posing a continued risk of transfer to the wearer during handling over multiple uses. The potential long-term survival of viruses on contaminated PPE is an

important factor when formulating recommendations for removal and handling of used PPE and reuse of PPE in the pandemic setting. It also highlights the continued importance of reinforcing good hand hygiene after PPE removal for preventing the spread of infection.

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