N95 mask disinfection: New evidence on how hospitals can effectively recycle key PPE

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Some hospitals continue to face a need to disinfect and reuse N95 face masks during the pandemic and a study from the University of Michigan shows that they can rely on moist heat or vaporized hydrogen peroxide to

inactivate viruses—but these treatments may leave behind other pathogens that are important to consider.

The research is the first full-scale study on N95 mask disinfection and reuse that evaluates multiple viruses, bacteria, and fungi along with how well masks filter and fit after treatment. It provides comprehensive information about multiple N95 disinfection methods, including their cost-effectiveness and ability to treat hundreds of masks each day.

As the pandemic begins to subside, fewer hospitals are needing to reuse PPE, but the FDA still lists N95s as in limited supply.

The study identified that the two approaches that can deactivate 99.99% of virus particles on these masks are: moist heat at 50% to 75% relative humidity and 176- to 180 degrees Fahrenheit for 30 minutes; and vaporized hydrogen peroxide obtained with a Bioquell Q10 whole room decontamination system. The moist heat specifications had not been previously identified.

"There are a lot of N95 reprocessing efforts going on at hospitals across the country and the world, but there hasn't been data to support whether the routes being taken were the right routes," said Krista Wigginton, a U-M associate professor of civil and environmental engineering who has been studying coronaviruses for several years.

"The most satisfying part of our results is how simple the solution can be," Wigginton said. "It's nice to know that you don't have to necessarily invest in some super fancy technology. Heating at 80 to 82 degrees Celsius with some added moisture is really effective."

Treatments don't eliminate other pathogens

But the findings raise new reasons for vigilance, says Nancy Love, the

Borchardt and Glysson Collegiate Professor and a professor of civil and environmental engineering at U-M.

"This paper shows, importantly, that while we are all focused on reducing risk of exposure to the virus that causes COVID-19, in reusing personal protective equipment, we cannot take our eye off the ball as it pertains to other infectious agents, including bacteria and spores, that have a long history of being problems in hospitals. So, any strategy in a hospital has to consider all these infectious agents. A multi-agent focus will likely require multiple decontamination steps or management practices to achieve infection control goals."

The pathogens the researchers tested are:

- Four viruses including a mouse coronavirus related to the SARS-CoV-2 virus that causes COVID-19, influenza A, and mouse hepatitis;
- Three bacteria including E. coli, Staphylococcus aureus—the bacteria that can lead to antibiotic-resistant MRSA infections, and Geobacillus stearothermophilus spores—commonly used as indicator organisms to measure whether items are sterile; and
- The fungus Aspergillus niger—commonly known as black mold.

Moist heat did not adequately inactivate G. stearothermophilus spores and vaporized hydrogen peroxide didn't inactivate S. aureus. Both raise important infection control implications, the study says. S. aureus is a hospital-borne infection that can colonize the nostrils of healthcare workers. And while G. stearothermophilus is merely an indicator organism, the fact that its levels weren't reduced enough suggests it may have implications for Clostridium difficile, or C. diff. This bacterium is increasingly becoming a problem in hospitals and its symptoms can range from diarrhea to dangerous colon inflammation.

Masks are no longer being reused at Michigan Medicine

While Michigan Medicine currently has enough PPE for healthcare workers, for a large part of 2020, the hospital reprocessed N95 face masks by treating them twice—once with moist heat and then in a supplementary short cycle of UV light. To achieve the moist heat requirements, the hospital purchased a humidity-controlled oven over the summer. They were able to process between 400 and 500 masks each day. As a back-up plan, they were also equipped to use vaporized hydrogen peroxide. Masks were clearly marked so they went back to their original user.

"N95 masks are critically important to the care of patients with COVID-19," said Keith Kaye, M.D., director of clinical research in the Michigan Medicine Division of Infectious Diseases and a collaborator on the study. "The process of evaluating and determining the most effective and safest way to disinfect masks has been multidisciplinary, collaborative and in my opinion hugely successful."

Before the new oven was available, and during testing, the hospital innovated. They adapted a washer intended to clean medical equipment and utilized only its drying abilities. They increased humidity in the ovens with wet towels.

Michigan Medicine did not reuse masks when caring for patients with C. diff.

Experimental methods and additional findings

The team began testing various methods in April 2020, focusing on three: ultraviolet light, moist heat and vaporized hydrogen peroxide.

While moist heat and vaporized hydrogen peroxide were found to be most effective, there are more obstacles to widespread use of hydrogen peroxide. It requires an expensive Bioquell instrument to generate a large and steady stream of the vapor and availability of that could be in question due to pandemic-related supply chain kinks. In addition, each treatment cycle takes about eight hours.

Moist heat requires the least amount of space, takes less than an hour per cycle and has relatively low maintenance costs.

To conduct experiments, the researchers sprayed or placed droplets of test viruses and other pathogens on masks and let them dry. They treated the masks at the hospital, then returned them to the engineering lab to assess how well the treatments worked.

In addition to evaluating whether each method killed pathogens, they also examined whether disinfected masks still filtered particles and maintained a seal on the face. They found that masks retained their original 95% filtration efficiency and fit after five cycles with either approach.

Over the course of their mask research, the team also discovered that different solutions used in the lab to transfer test viruses to masks can impact the results of studies on treatments with heat. They detail those findings in a separate paper titled "Humidity and deposition solution play a Critical Role in Virus Inactivation by Heat Treatment of N95 respirators." The researchers encourage future studies to clearly specify the solutions they use when depositing viruses on masks, and when possible, use the appropriate human material, which, in this case, would be saliva.

More information: Krista R Wigginton et al. Validation of N95 Filtering Facepiece Respirator Decontamination Methods Available at a

Large University Hospital, *Open Forum Infectious Diseases* (2020). DOI: 10.1093/ofid/ofaa610

Nicole Rockey et al. Humidity and Deposition Solution Play a Critical Role in Virus Inactivation by Heat Treatment of N95 Respirators, *mSphere* (2020). DOI: 10.1128/mSphere.00588-20