I Smell Smoke—The Must Know Details About the N95

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It was coronavirus disease (COVID-19) day 69 in the United States. 29 in New York State and 17 in New York Presbyterian Hospital. I (D.L.C.-L.) was halfway through an endoscopic retrograde on an intubated COVID-19-positive patient, wearing all of my mandated personal protective equipment (PPE), including the same N95 mask that I had worn throughout the day, with a covering surgical mask and welder’s-type face shield. Having just performed a sphincterotomy for choledocholithiasis, I realized I could smell the characteristic aroma of burning tissue as I withdrew the sphincterotome from the duodenoscope channel.

The following three issues struck me:

1. How much aerosolization occurs as accessories are removed from the endoscope channel while pressure is still being generated by the carbon dioxide in the duodenum?
2. How can I smell smoke while wearing an N95 mask?
3. Is this mask as good as it was when it was new now that I have worn it a few times?

The second issue has an answer—sorry, a lengthy one:

A respirator N95 mask is a single-use product cleared by the FDA and by the CDC NIOSH (National Institute for Occupational Safety and Health) to block passage of at least 95% of test particles of 0.3 μm size. Such particles may be bioaerosols or nonbiological aerosols and are trapped equivalently as dictated by particle size. But that is just the beginning of the story...

Factors affecting the efficacy of a respirator mask are as follows (1):

1. Its filtration characteristics
2. The ability of the microorganism to survive on the filter
3. The potential for reaerosolization of the bioaerosol
4. How the respirator may be reused
5. How the respirator is fitted
6. The assigned protection factor of the mask

Respirator masks usually use nonwoven fibrous filter media with fibers ranging from less than 1 to 100 μm in diameter to form a multilayer crisscrossing web. The spaces between the fibers allow for breathability. Fibers capture the particles by a variety of mechanisms—gravitational settling (larger than 100 μm), inertial impaction (larger than 0.6 μm), diffusion (smaller than 0.1 μm), and electrostatic attraction (all sizes depending on particle electrostatic charge) (Table 1) (1). Because of these mechanisms, especially the last one, smaller particles than the mask’s specifications may be trapped. A sneeze generates droplet nuclei ranging from 0.125 (the size of the virus itself) to 10 μm, with a median of 1 μm, which a respirator mask will trap with an efficiency from 95% to 99%. Typical airborne influenza particles, sampled from hospital rooms, range from less than 1 to 4 μm, but virus aerosols, such as influenza, experimentally sprayed at a respirator mask are blocked with 95% efficiency.

Microorganism survival on a respirator mask (without an integral biocide) is, in general, only relevant for contact contamination. Importantly, once used, the N95 is considered a fomite hazard, and its outer surface is considered contaminated (2). The steps for donning and doffing have been well described (Table 2) (3).

N95 respirators can only provide the expected level of protection against airborne particles when there is a good face seal. A “fit test” is exactly as the name describes: it helps to verify that the selected respirator can achieve an acceptable fit on a particular wearer’s face to ensure the expected level of protection. The nose and chin are the most challenging facial features that affect the fit. The commonly used chemicals, Bitrex (bitter) and saccharin, can test respirators with a particulate filter of any class (4,5). Thus, fit testing is different from testing of filtration efficiency because both aerosolized chemicals will be blocked by the mask and will only be detected by the wearer if there is a leak when the wearer inhales (6). The NIOSH-approved N95 respirators must pass the filter performance tests listed in the NIOSH’s regulations.

Smell is quite another matter. Smell detects molecules via our olfactory receptors. Sulfur with an approximate molecule diameter of 0.0004 μm is detectable by smell and could certainly pass through an N95 mask. Smoke particles, which are heterogeneous, tend to be larger at approximately 1 μm (7). However, some smoke particles can be small enough to pass through a mask, and odoriferous gases, such as hydrogen sulfide, may certainly do so. Thus, it is possible to detect certain molecules and particles by smell. It does not indicate that the mask is not functioning properly.

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Fogging of glasses, or other eye protection, can occur even with a properly functioning N95 mask, assuming that the mask was fit tested and a user seal check was performed after donning. When the wearer exhales, the inside of the N95 becomes positive pressured. Most of the warm exhaled air will pass through the mask, whereas some of the air may be expelled around the N95. A colder air temperature and any colder surface that is close by, such as the wearer’s spectacles, will allow condensation to occur and fogging is the result. This effect is also influenced by the ambient temperature and humidity. By contrast, when the wearer inhales, the negative pressure generated will collapse the N95 close to the face.

### Table 1. Particle size comparison chart (1,4–7)

| Object                                              | Size in μm | Comment                        |
|-----------------------------------------------------|------------|--------------------------------|
| Aerosol particles we may inhale                     | 10–100     | “Inhalable” can enter airway    |
|                                                     | 5–10       | “Thoracic” can reach large bronchioles |
|                                                     | ≤5         | “Respirable” can reach alveoli |
| Beach sand                                          | 250        |                                |
| Table salt                                          | 125        |                                |
| White blood cell                                    | 25         |                                |
| Red blood cell                                      | 6          |                                |
| Spores                                              | 2–5        |                                |
| Bacteria                                            | 0.3–10     |                                |
| Viruses                                             | 0.02–0.3   |                                |
| Hepatitis B                                         | 0.045      |                                |
| Adenovirus                                          | 0.08       |                                |
| Influenza                                           | 0.08–0.12  |                                |
| Coronavirus including SARS-CoV-2                    | 0.125      |                                |
| Droplet nuclei from sneeze/cough                    | 0.125–20   |                                |
| Droplet nuclei from influenza room                  | <1–4       |                                |
| Respirator mask particle trapping                   | 0.3        | 95% effective                  |
| Water molecule                                      | 0.0003     | 300 pm/0.3 nm                  |
| Hydrogen sulfide                                    | 0.00036    | 3.6 Å/360 pm/0.36 nm           |
| Carbon dioxide                                      | 0.00033    | 3.3 Å/330 pm/0.33 nm           |
| Smoke particles                                     | 0.0025–1.0 | 2.5–1.000 nm                   |
| Saccharin (MW 205 g/mol)                            | 0.0003     | 323 pm/0.3 nm                  |
| Denatonium (Bitrex) (MW 447 g/mol)                  | 0.0007     | 700 pm/0.7 nm                  |

### Table 2. The process of donning and doffing the N95

#### First time N95 respirator use:

**A. Donning**

Once the disposable N95 respirator is donned and the seal check is performed, a barrier will be placed over the N95 to protect it from surface contamination during care.

Procedure mask should be applied over the N95 respirator; goggles will be used too.

-OR-

Full-face shield should be worn over the N95 respirator.

**B. Doffing when a procedure mask barrier is used**

While in the patient’s room, remove the gown close to the doorway.

Perform hand hygiene over gloves.

Remove the procedure mask covering N95 and discard. The front is potentially contaminated so remove by holding by the ear loops.

Remove gloves.

Exit patient room.

Perform hand hygiene, don gloves, use a germicidal wipe to prepare a surface on which the eye goggles will be placed, and remove goggels.

Reusable eye goggles are disinfected using a germicidal wipe while observing manufacturers contact time per instruction for use.

Doff gloves and perform hand hygiene, and remove N95 respirator and perform hand hygiene.

After completing all doffing steps, store goggles for reuse and store N95 per storage instructions (Figure 1).

Perform hand hygiene.

**C. Doffing when a full-face shield barrier is used**

While in the patient’s room, ONLY remove the gown then gloves close to the doorway.

Perform hand hygiene.

Exit patient room.

Perform hand hygiene, don gloves, and use a germicidal wipe to prepare a surface on which the face shield will be placed.

Perform hand hygiene and remove the face shield. The front is potentially contaminated, so remove carefully by bending forward and using the elastic band.

Use a germicidal wipe to prepare a surface on which the face shield will be placed, and then remove face shield and disinfect before placing it on the prepared surface.

Face shield is disinfected using a germicidal wipe while observing manufacturers contact time.

Doff gloves, perform hand hygiene, remove respirator, and perform hand hygiene.

After completing all doffing steps, store face shield for reuse. Store N95 per storage instructions (Figure 1).

Perform hand hygiene.

**D. Storage of previously worn disposable N95 respirators**

After removing N95, visually inspect for contamination and distortion in shape/form. If contaminated/wet, creased, or bent, N95 should be discarded.
Table 2. (continued)

| Reuse of N95 |  |
|---|---|
| Remove N95 mask from paper storage bag and visually inspect for distortion. If creased or bent, do not reuse. |  |
| **Donning** |  |
| Perform hand hygiene |  |
| Don gown. |  |
| Don the N95 respirator (disinfected by UV). |  |
| Perform a negative/positive seal check by doing the following: |  |
| No air should be felt around the perimeter while blowing out. If you feel air coming out, it is not a tight seal. |  |
| When taking a small breath in, the mask should pucker in slightly. If it does not, it is not reusable. |  |
| When breathing out, you should feel the respirator expand slightly. If it does not, it is not reusable. |  |
| If it is not a tight seal, the respirator cannot be reused. |  |
| Ensure the mask is breathable; if unable to breathe in the mask, the respirator cannot be reused. |  |
| Perform hand hygiene and don goggles after seal check. |  |
| **Continuing donning order** |  |
| Don procedure mask with goggles or full-face shield over N95. |  |
| UV, ultraviolet. |  |
| Adapted as is from Nebraska Medicine (15). |  |

and air is forced to enter through the mask. Fogging does not, therefore, indicate mask failure (6,8).

The third issue—extending the life of a respirator mask—has some answers. Recommendations of standard PPE are evolving (see also Supplementary Figure, http://links.lww.com/AJG/B592). Many societies are issuing guidance on PPE based on COVID-19 disease prevalence, symptom screening, and availability of preprocedure testing. Many providers may opt to continue to use N95 masks as standard PPE, especially in high-prevalence areas or when test performance characteristics are not optimal.

In conventional times, the N95 is one-time use (9). In contingency and crisis times of COVID-19 with significant limitations in the supply chain of respirator masks, there is a need to use the N95 over an extended period, or even to reuse it. Extended use of the N95, which is preferred over reuse, is if you wear it without removing it between patients (2). Reuse refers to when you wear it over many encounters, removing it in between some of the encounters (Figure 1) (10). The CDC describes the reuse of N95 masks as a “contingency capacity strategy” to conserve supplies (9). When considering reuse of N95, the mask should be carefully inspected. If any component of the respirator is compromised, or if a successful user seal check cannot be performed, the mask should be discarded.

Given the severe shortage of the N95 masks, efforts are underway to decontaminate the N95 masks between use (11). The CDC recognizes decontamination methods as a “crisis capacity strategy.” These efforts are best coordinated at the hospital level because the fitting and/or the filtering capability of the masks can be significantly reduced by reprocessing processes, thus rendering the masks ineffective.

Please note that spraying the masks with isopropyl alcohol, wiping with chlorinated water, immersing in bleach, or individual efforts to decontaminate the mask with ultraviolet or ozone are not recommended. Severe acute respiratory syndrome coronavirus 2 has been shown to remain active for more than 3 days. Thus, overnight storage is also not a suitable method to decontaminate N95s.

In conclusion, although upper and lower endoscopy has always been an aerosol-generating procedure, we have not previously placed adequate attention to the potential for healthcare worker infection during endoscopy in this way, perhaps because it had unimportant clinical significance. The COVID-19 pandemic has changed the status quo (3). Endoscopy in all patients suspected or proven to have this infection will require proper PPE, which includes the use of the N95 respirator masks (12,13,14). In this COVID-19 crisis, proper care and handling of the N95 by the healthcare worker is essential to maintain the health and safety of providers so that we can continue to provide necessary care to our patients.
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CONFLICTS OF INTEREST
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