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Eye Protection in ENT Practice During the COVID-19 Pandemic

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Abstract

Objectives. There is a lack of evidence-based guidelines with regard to eye protection for aerosol-generating procedures in otolaryngology practice. In addition, some recommended personal protective equipment (PPE) is not compatible with commonly used ENT equipment. This study aims to investigate the degree of eye protection that commonly used PPE gives.

Study Design. Simulation model.

Setting. Simulation laboratory.

Methods. A custom-built setup was utilized to simulate the clinical scenario of a patient cough in proximity of a health care worker. A system that sprays a xanthan-fluorescein mixture was set up and calibrated to simulate a human cough. A mannequin with cellulose paper placed on its forehead, eyes, and mouth was fitted with various PPE combinations and exposed to the simulated cough. The degree of contamination on the cellulose papers was quantified with a fluorescent microscope able to detect aerosols $\geq$10 μm.

Results. When no eye protection was worn, 278 droplets/aerosols reached the eye area. The use of the surgical mask with an attached upward-facing shield alone resulted in only 2 droplets/aerosols reaching the eye area. In this experiment, safety glasses and goggles performed equally, as the addition of either brought the number of droplets/aerosols reaching the eye down to 0.

Conclusion. When used with an upward-facing face shield, there was no difference in the eye protection rendered by safety goggles or glasses in this study. Safety glasses may be considered a viable alternative to safety goggles in aerosol-generating procedures.

Keywords

personal protective equipment, eye protection, aerosol generating, COVID-19, otolaryngology

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The COVID-19 pandemic has highlighted the importance of appropriate personal protective equipment (PPE) use to prevent transmission of the infection to health care workers. Although the main route of transmission was initially thought to be via respiratory droplets, later research suggested that airborne transmission via respiratory aerosols may be possible.[1,2] As such, additional precautions have been advocated when health care workers perform aerosol-generating procedures. As a significant proportion of infected patients may be asymptomatic, appropriate PPE has to be worn even when interacting with patients who are well. This is especially so in otorhinolaryngology (ENT) practice as procedures are frequently performed in the upper aerodigestive tract, where viral load is highest.[3]

Unfortunately, in the context of ENT practice, the design of certain PPE, including powered air-purifying respirators, face shield, and safety goggles, is not compatible with some of the commonly used equipment, such as the operative microscope, headlight, and surgical loupes. As such, it is sometimes not possible for ENT surgeons to wear the gold standard enhanced PPE for airborne protection.

There is currently wide variation in guidelines on what constitutes appropriate PPE and a lack of evidence-based recommendations. This is especially so when it comes to PPE recommendations for adequate eye protection, which also has to be relevant and feasible in ENT practice. While safety goggles have been recommended over other methods of eye protection based on better protection over aerosols, there has been little evidence to support such recommendations. Aerosol-generating procedures are common in ENT practice, but some recommended PPE combinations are not compatible

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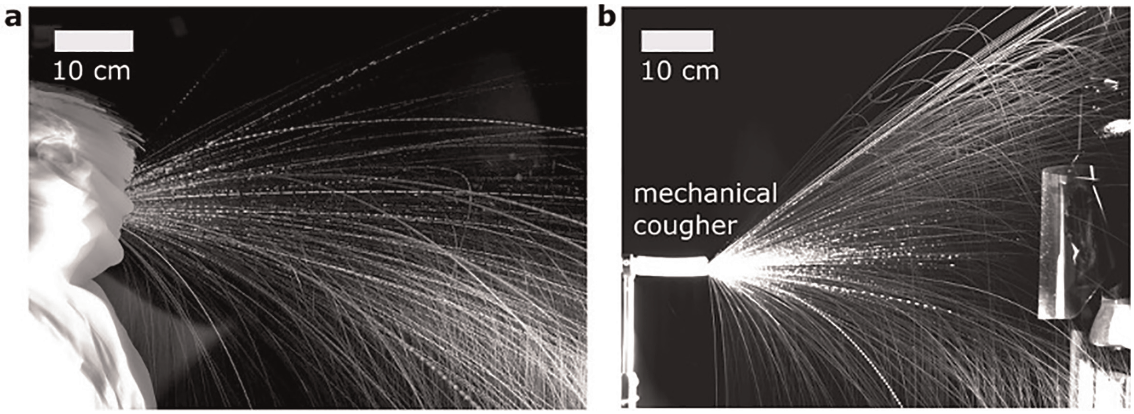

Figure 1. The trajectory of droplets generated by (a) a person coughing and (b) our mechanical cougher, as visualized by high-speed photography.

with commonly used equipment in ENT practice. This study aims to investigate the degree of protection that various PPE combinations give to rationalize their use during the COVID-19 pandemic.

Materials and Methods

This study utilized a custom-built setup to simulate the clinical scenario of a patient cough (aerosol generating) in proximity of a health care worker. A spray system was set up and calibrated to produce an airflow of 8 m/s for a duration of 250 ms, similar to the conditions found in a human cough.[4] High-speed photography confirmed that the range of droplet motion and trajectories are broadly similar for a human cough and our mechanical cougher (**Figure 1**). To simulate the viscosity of human saliva, we used 0.2 wt% xanthan gum dissolved in water. Additionally, we dissolved 0.1 mg/mL of fluorescein (from an ophthalmic strip) into the solution so that the droplets produced can be easily visualized under blue or ultraviolet light.

To test the effectiveness of the various PPE combinations, we placed a mannequin 30 cm away from the opening of the spray pipe, which is the estimated distance between a health care worker and a patient during an oropharyngeal examination. The following PPE combinations are tested:

- Control without any PPE
- N95 mask and surgical mask with attached upward-facing face shield
- N95 mask, surgical mask with attached upward-facing face shield, and safety glasses
- N95 mask, surgical mask with attached upward-facing face shield, and safety goggles

For each PPE combination, stress testing with 6 spray cycles was used. A total of 200 mg of liquid was expelled, as measured by a mass balance. In comparison, a human cough typically produces about 5 to 10 mg of liquid.[5]

The degree of contamination in each scenario is assessed by first placing cellulose filter papers (47 mm in diameter, 0.22-μm pore size; Triton, Millipore) on the mannequin's forehead, eyes, and mouth areas. The filter papers are collected after the 6 spray cycles in each scenario and the total amount of contamination is quantified by scanning an area of 3×3 cm with a fluorescent microscope (4× objective, Nikon TIRF system, 405-nm excitation) equipped with robotic stage and noting the number and radii of the fluorescein stains. The optical resolution of the imaging system is able to detect droplets that are $\geq$10 μm. After each scenario, the mannequin was thoroughly cleaned, and new filter papers were placed on it.

Ethics committee approval is not required for this study.

Results

Figure 2 summarizes the results for the different PPE combinations. Without any PPE (control), many droplets landed on the mannequin, and the fluorescein stains are clearly visible under ultraviolet light (**Figure 2a**). Individual fluorescein stains corresponding to individual droplets are also clearly visible on the fluorescent micrograph. We found that in the absence of PPE, there were 19, 278, and 166 fluorescein stains (range, 10-800 μm) in the forehead, eyes, and mouth area, respectively. The actual droplet size is likely to be significantly smaller than the fluorescein stain, because the droplet spreads into a larger stain when it contacts the filter paper.

In the tested PPE combinations, the N95 mask was able to effectively eliminate any droplets or aerosols $\geq$10 μm from reaching the mouth area (**Figure 2b-d**). This is in contrast to 166 droplets/aerosols that reached the mouth area when no mask was worn (**Figure 2a**).

The use of a surgical mask with an attached upward-facing shield alone was able to stop most droplets/aerosols from reaching the eye area under stress testing. Only 2 droplets/aerosols reached the eye area (**Figure 2b**), as opposed to 278 droplets/aerosols when no eye protection was worn in the control experiment (**Figure 2a**). In this experiment, safety glasses and goggles performed equally, as the addition of either safety glasses or goggles brought the number of droplets/aerosols reaching the eye down to 0 (**Figure 2c, d**).

In the absence of additional protective gear, none of the tested PPE combinations stopped droplets/aerosols from reaching the forehead/hair region (**Figure 2b-d**).

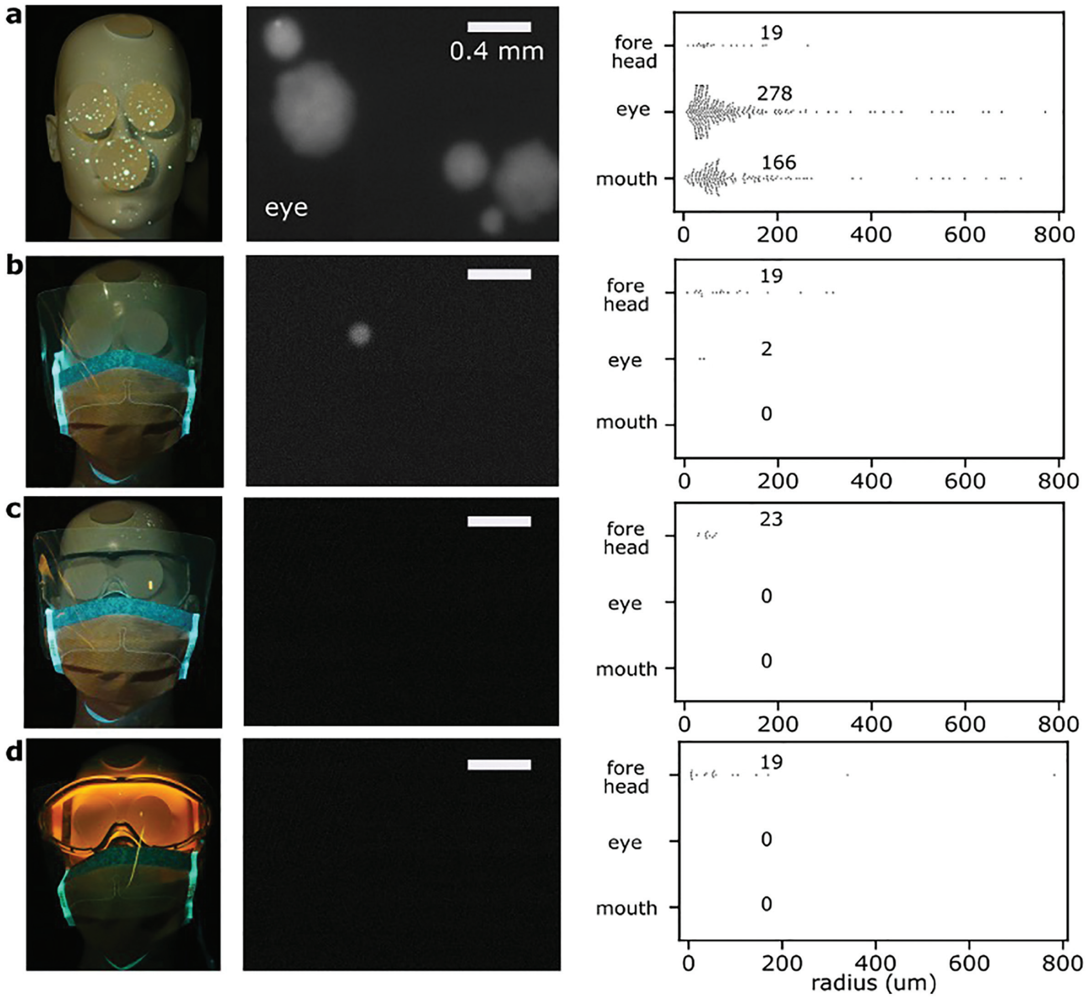

Figure 2. Fluorescein stains on the mannequin and filter paper when different personal protective equipment combinations were worn. The swarm plot shows the total number and size of fluorescein stains that landed on the mannequin's forehead, eyes, and mouth.

Discussion

Potential portals of entry of infectious agents include the oral/nasal airway and the conjunctival surfaces of the eyes. In ENT practice, clinicians often examine the upper aerodigestive tract in close proximity, perform aerosol-generating procedures, and frequently see patients with symptoms that overlap those in upper respiratory tract infections. In addition, a proportion of patients infected with COVID-19 are asymptomatic. As such, it has been advocated that enhanced PPE should be worn even when interacting with asymptomatic patients with unknown COVID-19 status, especially in the context of performing aerosol-generating procedures.[6-8]

While the N95 mask or the powered air-purifying respirator has been widely accepted as protection against airborne aerosols,[7] a recent study highlighted that transmission through the conjunctival surface should not be neglected.[9] Indeed, another study suggested that the addition of eye protection reduced transmission of COVID-19.[10] Frequently used PPE for eye protection includes safety googles, safety glasses, or face shields.[6-8,10,11] However, regular downward-facing shields, which are secured around the forehead, are not compatible with the microscope and most headlights. Safety goggles are not compatible with the use of the microscope and surgical loupes, while safety glasses cannot be used with surgical loupes. While surgery involving the necessary use of this equipment can be avoided in the short term, the COVID-19 pandemic is expected to be long drawn, and more sustainable solutions should be considered.

This study shows that the use of a N95 mask with an upward-facing face shield is able to drastically reduce the risk of any droplets or aerosols reaching the mouth or eye area, even under conditions of stress testing. These upward-facing shields are compatible with most ENT equipment.

Safety goggles are not compatible with the use of the microscope and surgical loupes. During surgery, it also tends to reduce the surgeon's nasal and peripheral vision. As the fit may not be airtight, especially for surgeons concurrently wearing glasses, the goggles are also more prone to fogging. Surgical issues aside, safety goggles are more difficult to safely doff due to their tight head strap. This may increase the risk of secondary contamination to the eye area during doffing, as studies have shown that health care workers are prone to contamination during the doffing process.[12] Additionally, since safety goggles are generally more uncomfortable than safety glasses, health care workers may be more prone to adjusting them, again increasing the risk of secondary contamination. The majority of safety goggles are also fitted with fabric straps, which are often difficult to decontaminate after use.

This study found that the addition of safety goggles or glasses to an upward-facing face shield further decreased the risk of eye contamination and that no aerosols/droplets $\geq$10 μm reached the eye area during the simulated cough. In this study, the safety goggles and glasses were worn with a face shield, which provides protection to exposed areas of the face and cheeks and should not be omitted. As no difference between safety goggles and glasses was found in this study, safety glasses may be a good alternative to safety goggles when they were worn with a face shield.

While our study attempted to pick up contamination with aerosols as small as 10 μm by utilization of a fluorescent microscope, a limitation was the inability to detect contamination by aerosols <10 μm. In the current literature, there is no agreed cutoff for the size of an aerosol, with different sources quoting a range between 2 and 100 μm.[11,13-18] It is possible that the study results would be different if aerosols <10 μm were accounted for. Nonetheless, this study provides an overview of the degree of protection that each PPE combination gives against droplets and larger aerosols, which are likely to contain a higher viral load.

Conclusion

The use of an upward-facing face shield, which is compatible with most ENT equipment, significantly reduces the amount of droplets and aerosols that land on the eye area. The addition of safety goggles or glasses further reduces the amount of contamination and performed equally in this study. There remains uncertainties and trade-offs that need to be carefully considered before deciding on the most appropriate PPE for each clinical situation.

Author Contributions

Jia Hui Ng, involved in study design and manuscript preparation; **Dan Daniel**, involved in conducting the study experiment and manuscript preparation; **Anton Sadovoy**, involved in conducting the study experiment and manuscript preparation; **Constance Ee Hoon Teo,** involved in study design and manuscript preparation.

Disclosures

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