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Improving protection from bioaerosol exposure during postoperative patient interaction in the COVID-19 era, a quality improvement study

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ABSTRACT

Purpose: During patient transport from operating room to post-operative recovery area, anesthesia staff are at increased risk of particle aerosolization from patients despite wearing face shields. Current single-use face shields do not provide anesthesia staff from adequate protection from bioaerosolized particles expired during a patient's cough, particularly during transfer from the operating room to the post-anesthesia recovery unit. In this study, we compare the efficacy of single-use face shield currently available at our institution to a newly designed face shield that provides better protection while still maintaining cost-effectiveness and the ease-of-use of a disposable device.

Materials and methods: A patient actor, simulated movements from a patient post-procedure, during transport from operating room to postoperative recovery area. Patterns of exposure of bioaerosolized particles produced from a cough between different face shields was evaluated using fluorescein dye.

Main results: More extensive coverage of the lower face, as provided by the Enhanced Protection Face Shield, offers improved droplet protection from bioaerosolized particles emitted from a cough.

Conclusions: Transfer from the operating room to the post-operative recovery unit is a hands-on process and involves managing multiple aspects of patient care physically. Current single-use face shields are convenient and cost-effective, but do not provide adequate protection from droplet aerosolization by patients during transfer. Other masks that provide adequate coverage are costly and are not designed to be single-use. A single-use disposable face shield that offers improved coverage of the lower face provides improved protection for anesthesia staff while maintaining cost-effectiveness, ease-of-use, and infection control.

1. Introduction

A new era has dawned on medicine with the emergence of SARS-CoV-2. Never before has a respiratory virus accelerated the reform of everyday common practices throughout the hospital. New challenges for protecting frontline healthcare workers present themselves daily, and meeting these challenges is of the utmost importance. In the early days of SARS-CoV-2, a facility in King County, Washington reported 129 cases during a 12-day period, and of those cases, 1 out of 4 of the RT-PCR-positive cases were in staff members [1]. Additionally, a study done by Rivett et al., the researchers utilized RT-PCR testing to determine that the asymptomatic rate of SARS-CoV-2 in a single institution was as high as 3% [2]. This finding raises the question of how many asymptomatic carriers throughout the hospital may unknowingly be carrying the virus from patient to patient.

The virus may spread from patient to healthcare worker by the generation of respiratory viral particles. These particles are formed by 3 mechanisms that are described in the literature as (1) open-close cycling of glottic structures, (2) high velocity gas flow, and (3) open-close cycling of terminal bronchioles [3]. The spread of these particles to the terminal bronchioles is of utmost concern as it is well known in literature that the smallest viral particles travel further distally in the respiratory tract. One of the first studies done on SARS-CoV-2 estimates the size of the viral particles to be between 0.06 μm and 0.14 μm [4]. Studies have been done to look at droplet spread during procedures that are believed to be of highest risk to produce respiratory viral particles, such as intubation and tracheostomies, using standard issued PPE including N95 respirators, eye protection, isolation gowns, and gloves [5]. Often, the combination of both N95 respirators, face masks, and face shields are used to offer maximum protection.

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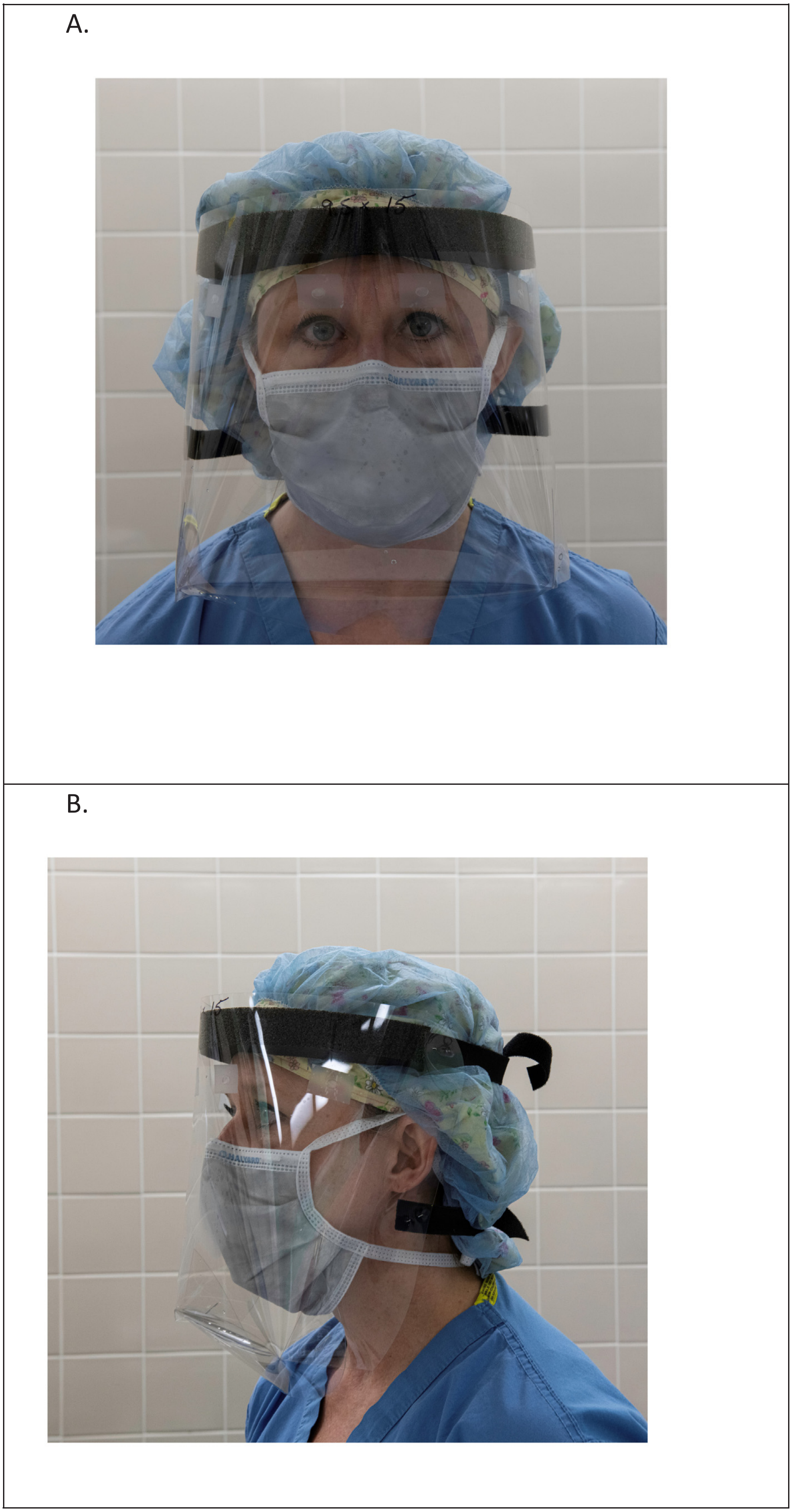

Fig. 1. A–B show the enhanced protection face shield used with, note the extensive lateral and inferior protection to respiratory droplets.

Fig. 2. A–B shows the institution wide standard APET control face shield.

We examined common procedures that may increase risk of exposure to SARS-CoV-2 that have not yet been studied in the literature. Using a review of the literature analyzing past outbreaks caused by coronavirus family viruses that also cause severe acute respiratory syndrome (SARS), we determined that the healthcare workers with the highest risk of exposure are those involved with intubation [6] and the pre- and post-operative care of patients. In a study by Kim et al., researchers observed 792 patients post-operatively for emergence

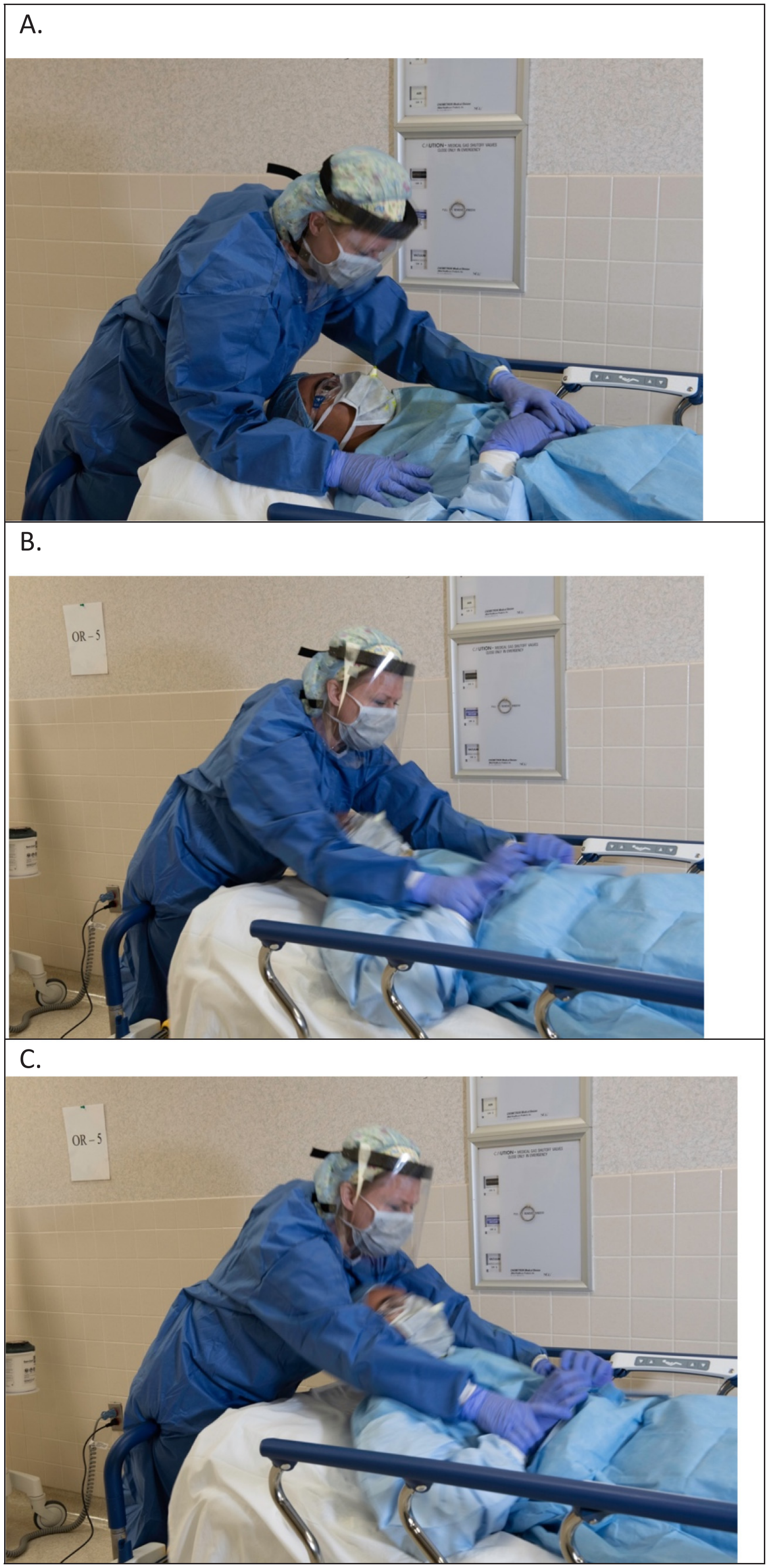

Fig. 3. A–C show positions during the anesthetist-patient interaction exposing the anesthetist wearing the EFPS to viral particles such as times when patients may attempt to remove an oxygen source and maintaining the arms of the patient by the patient side.

Fig. 4. Placement of atomization device through slit in face mask worn by patient actor.

agitation using the Richmond Agitation Sedation Scale and found that 1 in 5 post-operative patients experienced emergence agitation [7]. Of those experiencing agitation, 88% of patients were defined as restless agitation, 8 patients needed physical restraint, and 2 required benzodiazepines [7].

Based off these studies, we present a unique evaluation of a very common event in the hospital setting that may predispose to higher chances of exposure: the transport of an agitated post-operative patient. Further, we compared the standard single-use, disposable face shield to a newly developed face shield, the Enhanced Protection Face Shield (EPFS), in this context.

2. Materials and methods

The Enhanced Protection Face Shield was designed by a local company near our institution. It is a die cut sheet of 0.03 cm-thick, anti-fog coated, amorphous-polyethylene terephalate (APET), thermal plastic measuring 3 m by 4 m in its final form. Further cuts are created along the inferior lateral aspect to form a dual-tab locking system. Foam padding is attached along the superior rim of the plastic. Adjustable straps at the top and bottom allow for a customized fit. The EPFS is normally stored flat. The integral dual tab locking system, when locked into place before use, forms a lower facial barrier. This conformation effectively isolates the lower and lateral edges of the face from the surrounding environment as seen in Fig. 1A–B.

An institution-wide APET plastic control face shield (0.03 cm-thick with dimensions 22.8 cm × 25.4 cm, Fig. 2A–B) attached to a foam headband was evaluated in comparison to the EPFS. A standard face mask was worn beneath both face shields.

The efficacy of the EPFS was evaluated in a controlled setting. We analyzed the various maneuvers performed by gurney operators associated with post-operative transport of patients in our hospital. The nurse anesthetist performed common patient interactions (eg, maintaining the arms of the patient by the patient's side), preventing the patient from removing oxygen source (eg, a nasal cannula or an oxygen mask), and by protecting an agitated post-operative patient who may require closer observation during arousal from sedation Fig. 3A–C.

A "cough" was simulated using a mucosal atomization device (MAD™, Teleflex, Morrisville, NC) attached to intravenous tubing connected to a 20 mL syringe filled with fluorescein dye. The atomization device was held at the level of the mouth through a slit in a face mask worn by the patient actor, as seen in Fig. 4. According to the Teleflex manufacturer, the MAD™ tip atomizes fluids into a fine mist of particles 30–100 μm in size, similar to the size of particles expired through a cough [8]. The atomizer was used at instances during transport at which we observed to be of highest risk for exposure. Five milliliters of fluorescein dye was used during each trial, and each trial lasted 10 s.

Visualization of the dye of was performed by the activation of fluorescence via a 100-watt LED UV floodlight source emitting at the range of 380–420 nm. High-resolution still photography was recorded with a Nikon D850 camera. We further analyzed the droplet data on the standard face shield by quantifying the particles on the underlying mask per trial using MIPAR™ technology [9].

The anesthetist-patient interaction was simulated 5 times each per mask used. Between simulations, a new gown and face mask were used. Fig. 3A–C shows the various positions exposing the anesthetist to viral particles during the anesthetist-patient interaction. Face shields were wiped clean and reexamined under UV light to ensure no residual fluorescein remained from prior testing.

3. Results

A total of 10 tests were performed. The currently available standard-issued flat face shield was tested 5 times. The results of the first 5 trials using the standard face shield are shown in Fig. 5A–J. UV light examination demonstrated that the dye was scattered along the medial aspect of both arms and chest of the nurse anesthetist and on all parts of the standard face shield. More importantly, the dye was visible on the inferior aspect of the facemask once the face shield was removed. Several droplets of dye were seen on the superior portion of the facemask underneath the face shield. Next, the EPFS shield was tested 5 times in a similar method, and results using the EPFS shield are shown in Fig. 6A–J. Similar to the currently available flat face shield, dye was scattered along the medial aspect of both arms, chest and all aspects of the EPFS. However, unlike the flat face shield, no dye was present on the facemask once the EPFS was removed.

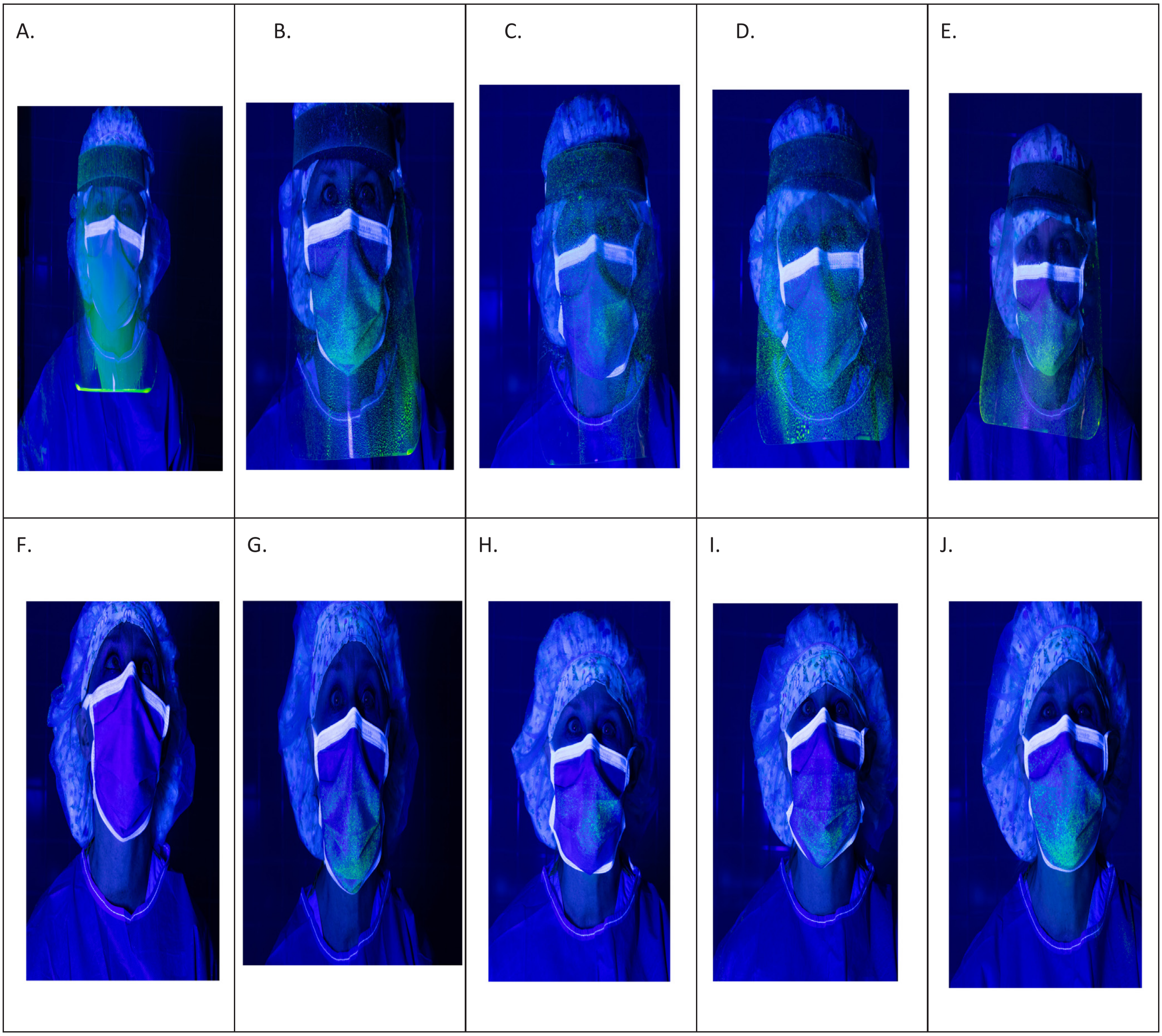

Fig. 5. A–J show the spread of droplets on the actor as well as on the face mask underneath the shield as seen under UV light when the standard face shield was worn.

4. Discussion

As otolaryngologists, we work closely with the anesthesia department, particularly in the operating room setting. It has been noted that anesthesiologists and nurse anesthetists are at increased risk of droplet contact during perioperative care, particularly during transfer of the post-operative patient to the post-operative recovery unit. During the time of the SARS-CoV-2 pandemic, there is an increased need for droplet protection and face shields have become a required part of personal protection equipment. There are many types of face shields available, ranging from single-use to multi-use. However, we have determined that single-use face shields do not provide adequate coverage. This is of particular concern when a patient, post-procedure, is awakening but is not yet completely conscious and is therefore unaware of their actions. During patient transfer, anesthesia staff transporting the patient are frequently hands-on, often leaning over the patient's head, and thus exposing areas of the face and neck that are not adequately protected by standard single-use face shields (Fig. 4A–C).

The newly designed single-use face shield (EPFS) provides improved coverage to the lower face and mandible area for anesthesia staff. Our study shows that when exposed to unpredictable bioaerosolization expired from a cough from a patient in the supine position, the EPFS provides enhanced coverage compared to the standard single-use face shield.

A study done by Lindsley et al. showed that almost 65% of particles expelled from a patient infected with Influenza contained viral DNA in the micron size able to reach the respiratory tract [10]. This led us to question the quantity of particles the anesthetist actor is exposed to when using the standard shield. We used MIPAR™ technology to determine the number of particles per mask. Table 1 lists the quantity of particles per mask in each of the trials with the standard face shield, with the droplet quantity as high as 12,000 droplets. Considering the findings in Lindsley et al., we could infer that during transport of post-operative patients, as many as 8000 droplets of SARS-CoV-2 could be dispersed onto the transporter.

To further demonstrate the need for an innovative face shield, we compared and analyzed the costs of single-use versus multi-use shields in comparison to the EPFS. The cost of a standard, disposable face shield from the manufacturer is listed as $5.79 per piece, while the cost for a polycarbonate multi-use shield was as high as $132.75 per piece

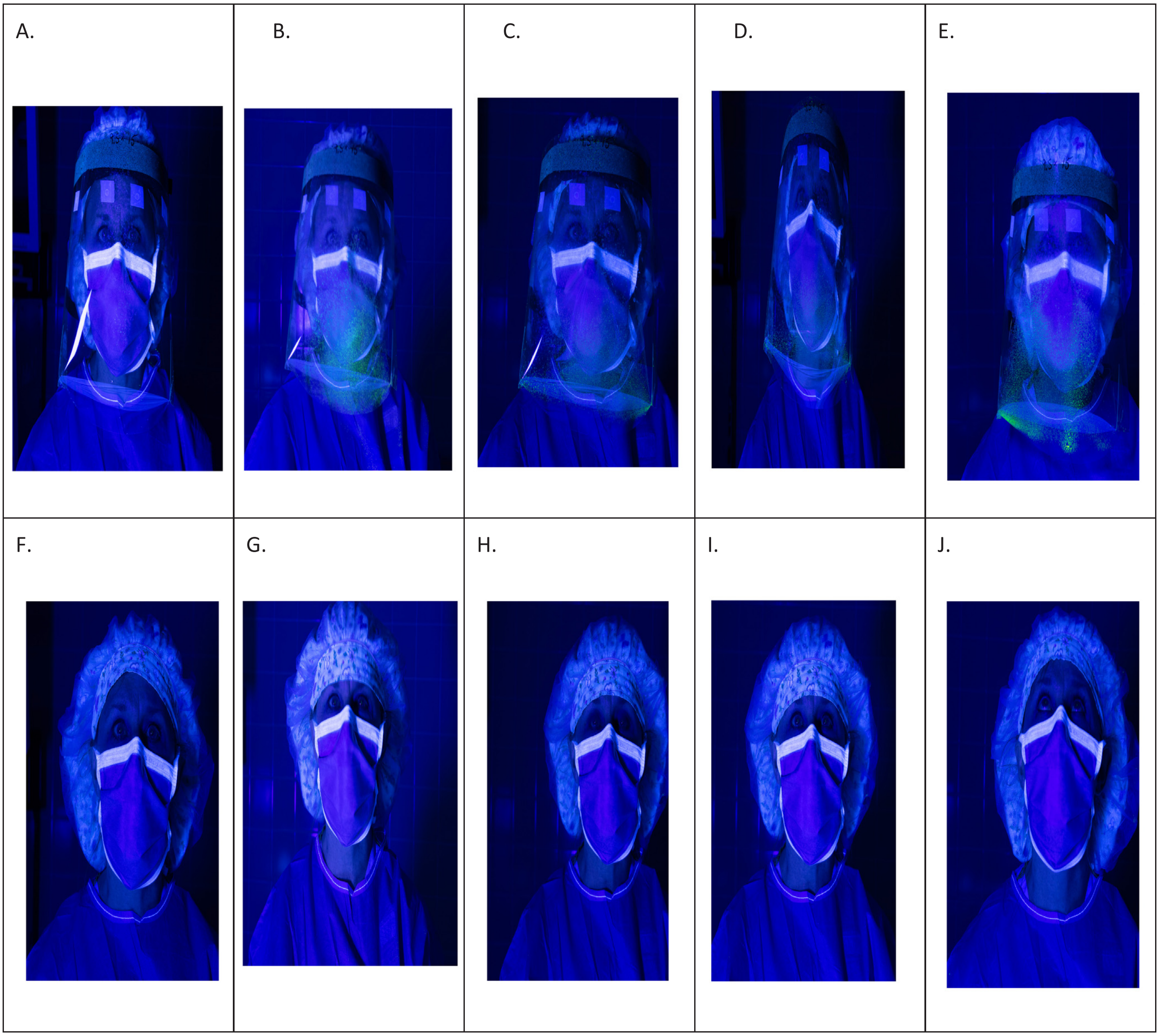

Fig. 6. A–J show the spread of droplets on the actor as well as on the face mask underneath the shield as seen under UV light when the EPFS was worn.

Table 1
Number of droplets using standard shield.

	Number of droplets
Trial 1	146
Trial 2	9280
Trial 3	6244
Trial 4	12,052
Trial 5	9326

[10]. In comparison, the estimated cost of the EPFS is $5.00, which is comparable to the current standard disposable shield.

The single-use, disposable feature obviates cleaning of the shield between patient encounters. Additionally, when multi-use shields are cleaned with a disinfectant wipe, it is impossible to ensure that it has been thoroughly decontaminated as cracks and corners may be inadvertently missed.

We conclude by reiterating the importance of adequately protecting our frontline heath care workers. Based on our close observation of the intimate proximity of anesthesia personnel to their patients during post-operative transport, there is inadequate protection provided by the current standard, single-use face shields from bioaerosolization expired from a patient during a cough. A single-use face shield that provides improved coverage for the lower face, such as the EPFS, provides more thorough protection while maintaining cost-effectiveness and ease-of-use.

Declaration of competing interest

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