

## ENDOSCOPY

# Minimizing endoscopist facial exposure to droplets: Optimal patient-endoscopist distance and use of a barrier device

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**Declaration of conflict of interest:** All authors have no conflict of interest to disclose.**Abstract****Background and Aim:** Minimizing endoscopist exposure to bodily fluids is important for reducing the risk of infection transmission. This study investigated the patient-endoscopist vertical distance necessary to minimize an endoscopist's facial exposure to a patient's visible droplets during upper gastrointestinal endoscopy and the ability of a new device to prevent droplets from reaching the endoscopist's face.**Methods:** A model was developed to simulate a patient experiencing a forceful cough during an upper gastrointestinal endoscopy with a model endoscopist. Fluorescent dye was expelled from the model patient's mouth towards the model endoscopist during simulated coughs; dye adhesion to the model endoscopist's face was evaluated using ultraviolet light. The simulation was repeated with the model patient positioned 70–100 cm above the floor, with and without a barrier to shield the patient's face. The accuracy of the cough simulation model and the relationship between patient-endoscopist vertical distance and endoscopist's facial exposure were evaluated.**Results:** The flow dynamics of the cough simulation model were similar to that of an actual human cough. There was a significant inverse correlation between the patient-endoscopist vertical distance and the model endoscopist's facial exposure, with positive exposures decreasing from 87% at 70 cm to 0% at 100 cm ( $P < 0.001$ ). The barrier device prevented facial exposure to droplets at all distances.**Conclusions:** We found that positioning the patient at least 100 cm below the top of the endoscopist's head or using a barrier device minimized the endoscopist's facial exposure to visible droplets during upper gastrointestinal endoscopy.**Introduction**

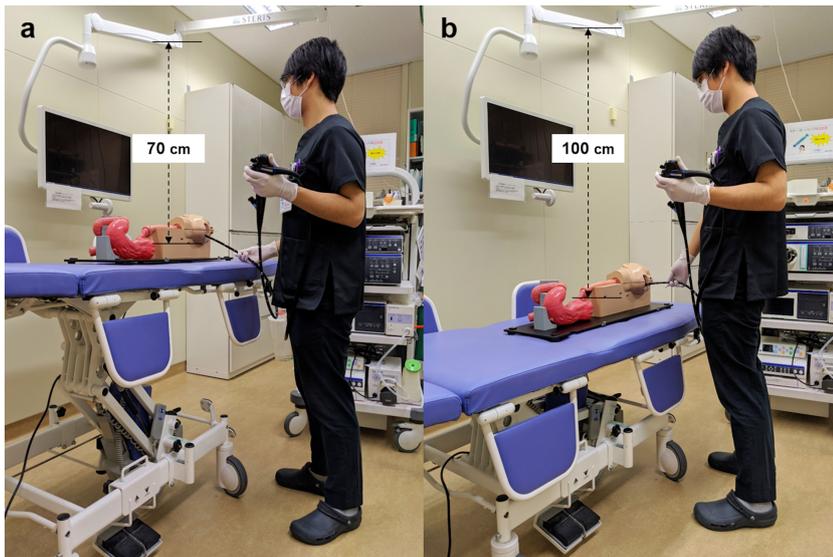
Infectious agents can be transmitted to healthcare providers during endoscopy procedures.<sup>1</sup> The coronavirus disease 2019 (COVID-19) pandemic that began in early 2020, caused by severe acute respiratory syndrome coronavirus-2 (SARS-CoV-2), heightened the concerns of healthcare providers, including personnel in endoscopy centers, regarding prevention of viral transmission from patients. Despite the absence of clear supportive evidence, endoscopy could potentially generate droplets and aerosols of biological fluids that could mediate transmission of various infectious agents.<sup>2,3</sup> In the COVID-19 era, minimizing the risk of respiratory virus transmission during endoscopy has become more important.<sup>3</sup>

The endoscopist's face has a high risk of exposure to body fluids and is prone to viral transmission through the mucous membranes of the eyes, nose, and mouth. For this reason, it is recommended that endoscopists wear masks and goggles, or face shields, to protect their faces.<sup>2,4–6</sup> However, such personal protective equipment (PPE) cannot completely protect the face. Further, the limited availability of such PPE during the

COVID-19 pandemic has necessitated the reuse of these devices. To reduce the risk of pathogen transmission during endoscopy and rationalize PPE use during the COVID-19 pandemic, minimizing the exposure of the endoscopist's face to procedure-generated respiratory droplets is important.

Table height and, therefore, the vertical distance between the patient and the endoscopist during an upper gastrointestinal (GI) endoscopy (Fig. 1) may be related to the degree of the endoscopist's facial exposure to respiratory droplets. To date, this relationship and the patient-endoscopist vertical distance necessary to minimize endoscopist's facial exposure to respiratory droplets have not been investigated. In clinical practice, the table height and the patient-endoscopist vertical distance is based on the endoscopist's preference.

In order to investigate the endoscopist's facial exposure to respiratory droplets in coughing, we first developed a forceful cough model and validated the accuracy of the cough simulation model by comparing it with the measurements of an actual human cough. We then aimed to determine the patient-endoscopist vertical distance necessary to minimize facial exposure to a



**FIGURE 1** Models at vertical distance between patient and endoscopist tested in this study. (a) The vertical distance between patient and endoscopist is 70 cm, which is the shortest setting in this study. (b) The vertical distance between patient and endoscopist is 100 cm, which is the longest setting in this study. [Color figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

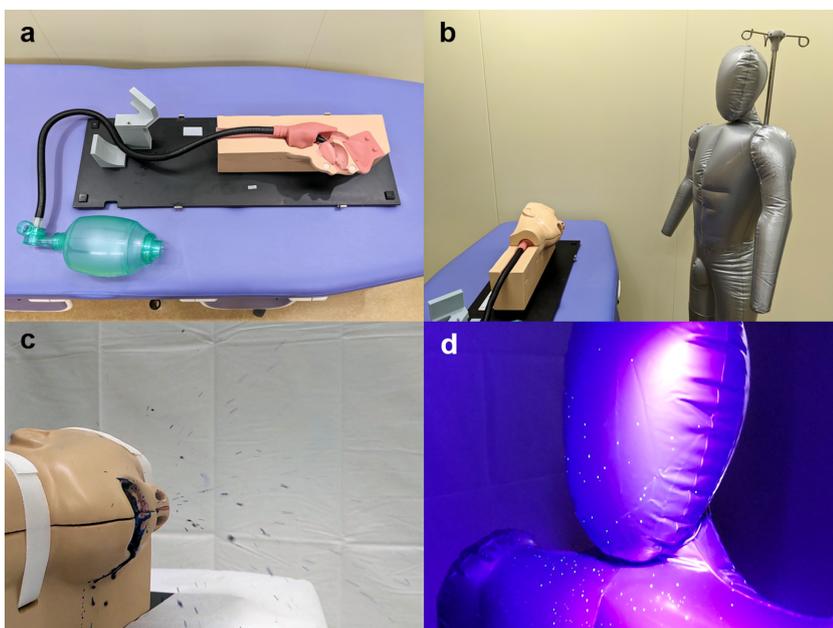
patient's visible droplets. We also investigated the ability of a simple barrier device to prevent flying droplets from reaching the endoscopist's face.

## Methods

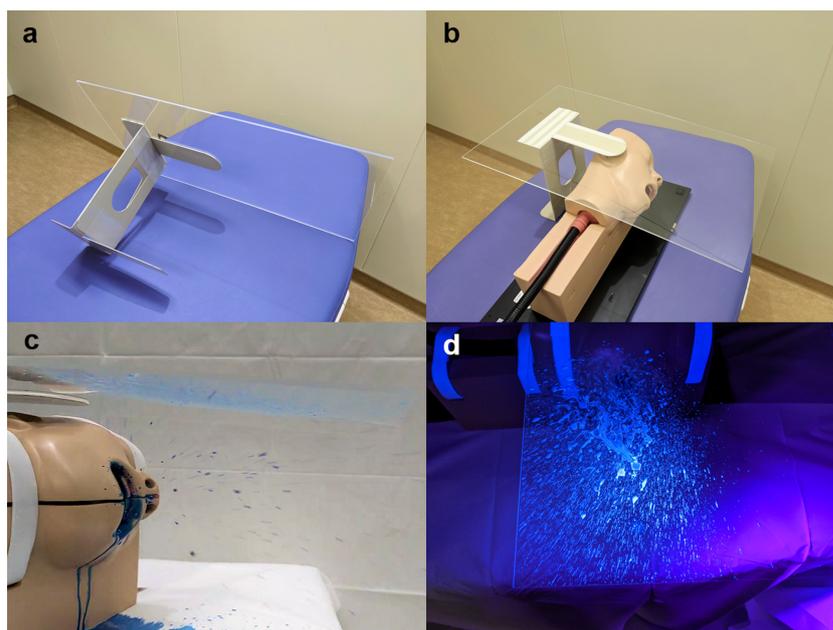
**Forceful cough simulation and droplet generation.** To simulate the respiratory droplets ejected from a patient's mouth during upper GI endoscopy, we developed a forceful cough model using endoscopy training mannequins and a respiratory bag. In this model, a 15-mm diameter tube was passed through a mannequin's esophagus (EGD simulator, LM-103, Koken, Tokyo, Japan), with the tip of the tube being fixed to the mannequin's oropharynx (Fig. 2a); a 1.5-L volume respiratory bag (NK-2347,

Nakamura Medical Industry, Tokyo, Japan) was connected to the other end of the tube. By compressing the respiratory bag as forcefully as possible, a portion of the 9.5-mL volume of 0.1% indigo carmine and 0.5-mL volume of fluorescent dye, contained within the tube, was expelled through the mannequin's mouth. The respiratory bag was compressed 10 times during each cough simulation.

**Barrier device.** We developed a simple barrier device to help reduce endoscopist exposure to respiratory droplets during upper GI endoscopy.<sup>7</sup> The device consists of two bookstands, taped together, with a piece of transparent acrylic (54 × 32 cm) attached to one bookstand (Fig. 3a). The device is positioned to shield the endoscopist's face (Fig. 3b) from upwardly propelled droplets



**FIGURE 2** Cough simulation and facial exposure evaluation. (a) A model simulating a forceful cough was developed using an endoscopy training mannequin and a respiratory bag. (b) The model patient is placed on the center of the table and a model endoscopist (170 cm tall) is positioned 60 cm in front of the model patient's face. The vertical distance between the patient and endoscopist models is 70 cm. (c) A solution containing indigo carmine and fluorescent dye is expelled from the mouth of the model patient towards the model endoscopist. (d) Facial exposure to the dye is evaluated using ultraviolet light. [Color figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]



**FIGURE 3** Barrier device. (a) A barrier device is shown, consisting of two bookstands and a transparent acrylic board (54 × 32 cm). (b) The device is placed to shield the patient's face and space in front of their face. (c) The device prevents the upwards travel of droplets released from the model patient's mouth during a simulated cough. (d) The fluorescent dye is evident on the bottom of the transparent shield after a simulated cough. [Color figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

released from the patient's mouth, reducing the endoscopist's facial exposure (Fig. 3c,d). The device can be cleaned using water mixed with detergent and then disinfected using 70% ethanol and 1% potassium peroxymonosulfate after the procedure, just as non-critical medical equipment. The device can then be reused after the disinfection process.

**Study outcomes.** We aimed to validate the accuracy of the cough simulation model as compared with the measurements of actual human cough and then determine the vertical distance between patient and endoscopist that prevented the endoscopist's face from being exposed to droplets from the simulated cough.

Flow dynamics, such as the velocity and amount of air, and the maximum distribution distance of droplets expelled from the cough model were first evaluated as follows: The respiratory bag used in this cough model was connected to a spirometer (CHESTAC-8900, Nihon Kohden, Tokyo, Japan), and the peak flow rate (L/s) and expired volume (L) expelled by compressing the respiratory bag were measured. The peak flow rate and expired volume were the values of peak expiratory flow and forced vital capacity measured by the spirometer, respectively. The maximum distribution distance of droplets expelled from the cough model was the horizontal distance from the mouth of the model positioned 90 cm above the floor to the farthest point of the adhesion of the dye on the floor. Simulations were performed 15 times to evaluate each outcome. A study of human cough flow dynamics using a spirometer reported that the peak flow rate of cough in adult male was 3–8.5 L/s and the expired volume was 0.4–1.6 L.<sup>8</sup> Several studies reported that respiratory droplets generated in sneezing or coughing on human could travel horizontally to 1.4–2.5 m from the subjects.<sup>9–11</sup> We determined that our cough simulation model would be simulating an actual human cough if the values of the flow dynamics and maximum distribution distance of 15 simulations were within the ranges reported for human

coughs (peak flow rate: 3–8.5 L/s, expired volume: 0.4–1.6 L, distribution distance: 1.4–2.5 m).

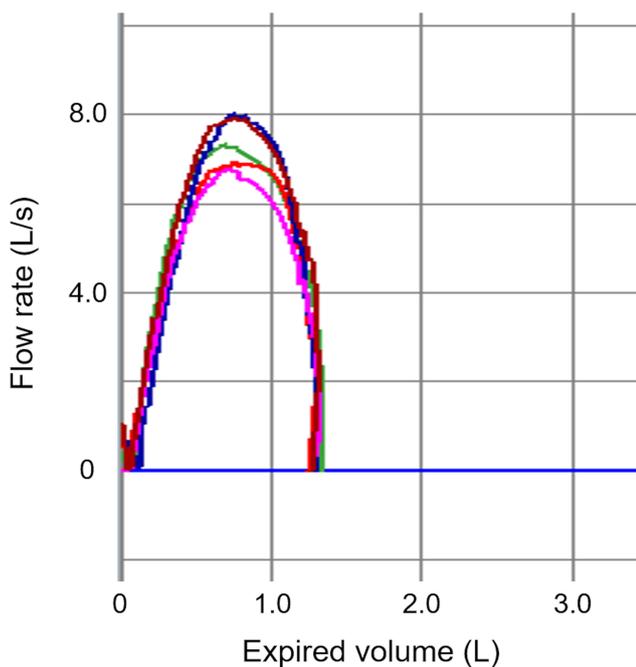
For our second study aim, we defined the patient-endoscopist vertical distance as the difference of positions between the top of the endoscopist model's head and the lower corner of the mouth of the patient model above the floor. An endoscopy training mannequin, mimicking a patient, was placed on the center of a table; a second mannequin, mimicking an endoscopist (height, 170 cm; face proportions, 25 × 20 cm), was placed in a standing position in front of the model patient (Fig. 2b) at 60 cm away from the mouth of the model patient. Because the table in our endoscopy center can lift the patient model to a maximum of 100 cm, which was 70 cm from the top of the endoscopist model's head, we set this point as the shortest vertical distance in this study. The model patient's position was changed from 100 to 70 cm above the floor, in 10-cm increments; cough simulations were performed at each position (Fig. 2c). Images of each distance between the patient and the endoscopist are shown in Figure 1. Following each simulated cough, the model endoscopist was illuminated with ultraviolet light to visualize the spread of the dye and to evaluate the adhesion of the dye to the face (Fig. 2d). The face of the endoscopist model was cleaned between simulations. This study focused on visible droplets with ultraviolet light caused by the cough model. The presence (positive exposure) or absence (negative exposure) of the dye on the face or head of the model endoscopist was determined for each simulation. The patient-endoscopist vertical distance at which negative exposures were observed for all cough simulations was investigated.

The secondary outcome was the determination of the extent of exposure reduction provided by the barrier device. The barrier device was placed between the endoscopist and the head of the model patient, with the transparent barrier covering a 20-cm distance in front of the model patient's mouth during the cough simulations. The patient-endoscopist vertical distance that resulted in no exposure to the model endoscopist's face was investigated.

**Sample size calculation and statistical analysis.** No exposure was defined as only negative exposures to the face of the model endoscopist occurring during each simulation at a specific patient-endoscopist vertical distance. At the patient-endoscopist vertical distance that provided no exposure, the expected proportion of negative exposures was 100%, with a threshold value of 80% negative exposures being deemed unacceptable. Thus, with a power of 80% and an alpha of 0.05, at least 13 simulated coughs were required at each patient-endoscopist vertical distance. Assuming a simulation procedure error rate of 10%, 15 simulation procedures were planned for each patient-endoscopist vertical distance. The relationship between the proportion of positive facial exposure and each vertical patient-endoscopist distance was analyzed using the Cochran–Armitage test for trend, and *P* values were considered statistically significant if  $<0.05$ . Statistical analyses were performed using R 3.5.2 software (R Foundation for Statistical Computing, Vienna, Austria).

## Results

**Flow dynamics of the cough simulation.** The peak flow rate and expired volume of the model-simulated coughs are shown in Figure 4, and maximum distribution distance of the dye from the simulated cough is shown in Figure 5. In the 15 cough simulations, the mean peak flow rate of the simulated cough was 6.9 L/s (range: 5.2–8.0 L/s), and the mean expired volume of the simulated cough was 1.4 L (range: 1.3–1.4 L), which were confirmed to accurately simulate a human cough (peak flow rate:



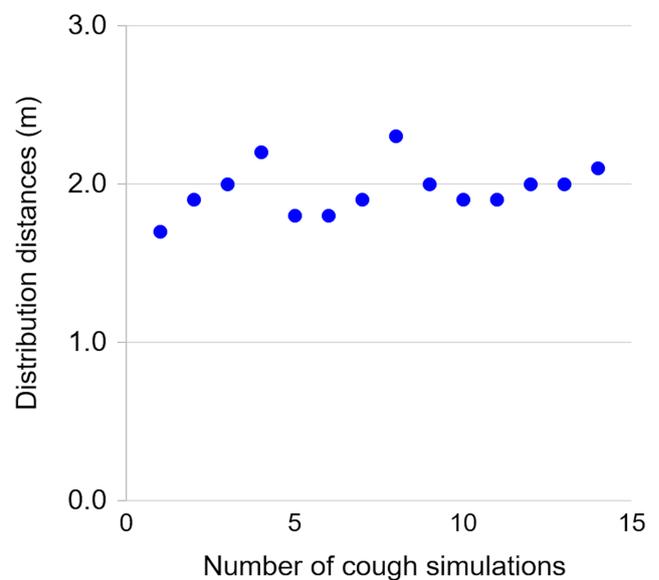
**FIGURE 4** Flow dynamics of simulated coughs. The peak flow rates of simulated coughs ranged from 6.8 to 8.0 L/s, and the expired volumes of cough simulations ranged from 1.3 to 1.4 L in 5 of 15 simulations. [Color figure can be viewed at [wileyonlinelibrary.com](#)]

3–8.5 L/s, expired volume: 0.4–1.6 L). The mean maximum distribution distance of the dye from the model's mouth in the 15 simulated coughs was 1.9 m (range: 1.6–2.1 m), which also accurately simulated the distribution distance of a human cough: 1.4–2.5 m.

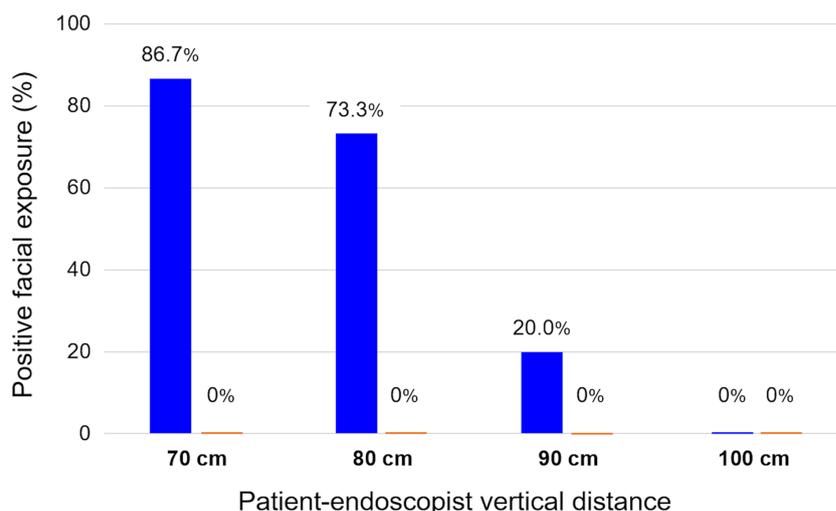
**Relationship between patient-endoscopist vertical distance and endoscopist facial exposure.** The relationship between the patient-endoscopist vertical distance and the model endoscopist's facial exposure to simulated visible droplets was evaluated in 60 simulations (15 simulations at each distance). There was a significant inverse correlation between patient-endoscopist distance and positive facial exposure ( $P < 0.001$ ) (Fig. 6). The proportion of positive exposures decreased as the patient-endoscopist distance increased; no detectable exposure occurred when the patient-endoscopist vertical distance was 100 cm. Video S1 shows one simulated cough when the patient-endoscopist vertical distance was at 70 cm; positive facial exposure is shown.

### Reducing facial exposure using a barrier device.

The model endoscopist's facial exposure to visible droplets when the barrier device was in place was evaluated in 60 simulations (15 simulations at each distance). When the barrier device was in place to shield the model patient's mouth and area in front of the mouth, the model endoscopist was completely protected from facial exposure to the simulated respiratory droplets (Fig. 6). Moreover, the highest point on the model endoscopist that was exposed to simulated respiratory droplets was equal to the height of the transparent barrier. Thus, the chest of the model endoscopist was not exposed to the droplets at levels above the height of the barrier device.



**FIGURE 5** Maximum distribution distance of the dye in cough simulations. Maximum horizontal distribution distances of visible droplets expelled from the cough model range from 1.6 to 2.1 m in 15 simulations. [Color figure can be viewed at [wileyonlinelibrary.com](#)]



**FIGURE 6** Relationship between patient-endoscopist vertical distance and model endoscopist facial exposure to droplets. The proportions of simulated coughs, with and without the use of the barrier device, that were positive for model endoscopist facial exposure at each patient-endoscopist vertical distance are shown. The patient-endoscopist vertical distance was measured from the top of the endoscopist model's head to the lower corner of the mouth of the patient model. ■, Without a barrier device; ■, With a barrier device. [Color figure can be viewed at [wileyonlinelibrary.com](http://wileyonlinelibrary.com)]

## Discussion

This is the first study to investigate the relationship between patient-endoscopist vertical distance and endoscopist facial exposure to respiratory droplets from the patient and the first to determine the optimal positioning of the patient to prevent such droplets from reaching the endoscopist's face during upper GI endoscopy. We developed a cough simulation model and evaluated its accuracy by comparison with the measurements of actual human coughs. Our cough simulation model provided flow dynamics and distribution distances of droplets comparable with those of actual human coughs. Therefore, we believe that the study outcomes of the relationship between the patient-endoscopist vertical distance and the endoscopist facial exposure to visible respiratory droplets can be evaluated as realistic human coughing. This study showed that when the patient's mouth was positioned at the 100 cm below the top of the endoscopist's head, the endoscopist's face was not exposed to droplets during simulated coughing. Further, the use of a simple barrier device completely protected the endoscopist from facial exposure to droplets, regardless of the tested patient-endoscopist vertical distance.

Endoscopy personnel has a high risk of exposure (via their faces, eyes, and skin) to infectious body fluids during endoscopy.<sup>12</sup> Regardless of the patient's infection status, control measures are necessary to minimize the risk of facial exposure to potential pathogens. Johnston *et al.* reported that there is a significant risk of the endoscopist's face being exposed to potential pathogens during endoscopy,<sup>13</sup> possibly resulting in the transmission of infectious disease. In our study, patient positions that increased the distance between the patient and the endoscopist were associated with reduced endoscopist facial exposure to droplets, with no facial exposure occurring when the patient was positioned 100 cm below the top of the endoscopist's head. The adoption of this working distance may reduce contamination of the endoscopist's face shield and result in reduced pathogen transmission risk during upper GI endoscopy.

Although endoscopists are recommended to wear appropriate PPE during endoscopy,<sup>2,4,14,15</sup> there is limited availability of such PPE during the present COVID-19 pandemic due to the global

demand for these devices.<sup>16</sup> Moreover, these devices are being reused or the same device is being used for multiple patient procedures, even on multiple days, increasing the risk of SARS-CoV-2 transmission for both endoscopists and patients. Hence, the adoption of a patient position that is 100 cm lower than the endoscopist's height may reduce facial PPE contamination, even in situations where PPE are reused.

For some endoscopists, positioning a patient 100 cm lower than their height may be too uncomfortable for performing upper GI endoscopy; this situation is shown in Figure 1. In particular, it could be difficult for endoscopists shorter than 170 cm to maintain that distance. In such instances, they must try to maintain the largest patient-endoscopist vertical distance to reduce their facial exposure, in particular, because we found a significant inverse correlation between patient-endoscopist distance and facial exposure.

We also recommend using the barrier device to minimize facial exposure to respiratory droplets, regardless of patient position. Recently, various barrier devices have been developed to reduce intraprocedural bodily fluid exposure during upper GI endoscopy using a ventilation mask or a transparent plexiglass cube.<sup>17,18</sup> Such devices may be more effective than our device for reducing exposure to body fluids because they completely shield the patient's mouth and nose from the operators.

This study has some limitations. First, 15 cough simulations for each distance constitutes a small sample size that may not be sufficient to support the study conclusions. Second, although our model is believed to reflect actual cough dynamics, the amount of the expelled dye solution may differ from the respiratory droplets expelled during an actual cough. Also, as only large size droplets that could be visualized under ultraviolet light were evaluated in this study, our results do not apply to airborne transmission. Future studies should investigate cough dynamics and transmission risk, including aerosol or airborne transmission, in actual human subjects. Potential methods that can be used for such analysis include computational fluid dynamics (CFD) and genetic testing for pathogens. CFD is a simulation method analyzing fluid flows using numerical analysis and data structures. Several studies using the CFD model investigated the flow dynamics of respiratory

droplets, including invisible small particles, in human subjects and revealed that microdroplets or airborne droplets in human cough can travel further than 2 m.<sup>19,20</sup> As for genetic testing, SARS-CoV-2 RNA has been detected by reverse transcription-polymerase chain reaction in swab samples collected on environmental surfaces and on the surface of face masks.<sup>21</sup> The combined analysis of CFD of patient coughs and genetic testing for pathogens sampled on different surfaces, including PPE, may provide a more accurate picture of transmission risk to help reduce the endoscopist's facial exposure to real human coughs during endoscopy. Finally, we wish to emphasize the risk of horizontal spread of infectious droplets to parts other than the face of the endoscopist. This study focused only on the risk of facial exposure during endoscopy and did not investigate exposure to other body parts. As Video S1 shows, the droplets can also spread horizontally, thus exposing the endoscopist's gown and gloves even if an adequate patient-endoscopist vertical distance is respected or the barrier device is used. Exposure to body parts other than the face also carries transmission risk, and endoscopists should also be aware of this.

In our realistic simulation, a patient-endoscopist vertical distance of at least 100 cm resulted in the model endoscopist avoiding facial exposure to simulated visible droplets from a patient coughing during an upper GI endoscopy. Similarly, the use of a device that shields the area in front of a patient's mouth completely prevented the endoscopist's facial exposure, regardless of the patient-endoscopist vertical distance. Thus, adopting the recommended 100 cm patient-endoscopist vertical distance or using a barrier device may reduce the endoscopist's facial exposure to visible droplets of bodily fluids and the consequent risk of pathogen transmission, during upper GI endoscopy.

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## Supporting information

Additional supporting information may be found online in the Supporting Information section at the end of the article.

**Video S1:** One simulated cough with the patient-endoscopist vertical distance at 70 cm. A model simulating a forceful cough during upper gastrointestinal endoscopy using mannequins is shown. After one simulation at a patient-endoscopist vertical distance of 70 cm, the facial exposure to the dye is evaluated using ultraviolet light.

**Video Link:** [https://drive.google.com/file/d/1h54Saco29-rRzYsgFv42Y5rPrL\\_Gfg/view?usp=sharing](https://drive.google.com/file/d/1h54Saco29-rRzYsgFv42Y5rPrL_Gfg/view?usp=sharing)