

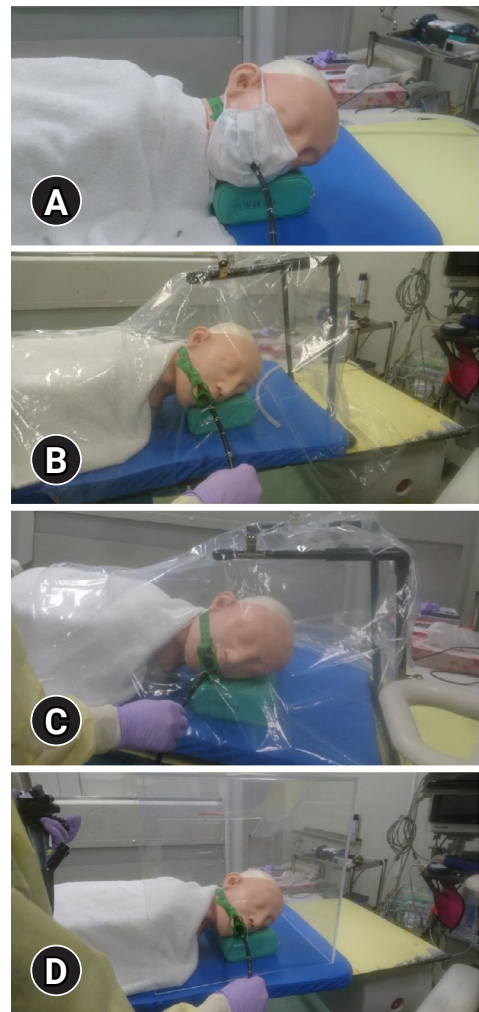
# A comparison of the effectiveness of four aerosol shielding devices in reducing endoscopists' exposure to airborne particles during simulated upper gastrointestinal endoscopy

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The coronavirus disease-2019 (COVID-19) pandemic has highlighted the importance of reducing the risk of infection through aerosol generation. Aerosol particles  $\geq 5 \mu\text{m}$  and  $< 5 \mu\text{m}$  in diameter are referred to as droplets and airborne particles, respectively. Since upper gastrointestinal (GI) endoscopy is an aerosol-generating procedure,<sup>1</sup> several novel devices have been proposed to reduce the exposure of the endoscopist to aerosol particles.<sup>2-5</sup> However, there is insufficient scientific evidence for the efficacy of these devices. While some of these devices have been examined using simulated cough-producing fluorescent droplets,<sup>2,5</sup> these simulations did not evaluate small invisible droplets or airborne particles.

Using an *in situ* simulation model, four proposed devices (modified mask [Fig. 1A], vinyl box with and without continuous suction [Figs. 1B, C], aerosol box [Fig. 1D], and no device [control]) were compared in terms of the exposure of the endoscopist to airborne particles. The simulation was performed in a self-contained endoscopy room with nine room air changes per hour. Upper GI endoscopy was performed by six endoscopists on a mannequin with a mouth guard, using a 9.9-mm flexible video GI scope (GIF-H290; Olympus Japan Limited, Tokyo,



**Fig. 1.** Overview photographs for tested devices. (A) Modified mask. (B) Vinyl box with continuous suction. (C) Vinyl box without suction. (D) Aerosol box.

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Japan). To simulate a strong cough, saline was sprayed via a 0.4-MPa pressure atomizer nozzle, placed in the mannequin's hypopharynx.<sup>5-7</sup> Simulated upper GI endoscopy was performed for five minutes on a mannequin. After device removal, the airborne particles were counted for one minute. A cough was generated every 30 seconds using a spray containing saline. The exposure of the endoscopist to airborne particles (0.3–2  $\mu\text{m}$ ) was measured using a portable HHPC6+ handheld particle counter (Beckman Coulter Inc., Brea, CA, USA). A detailed description of the methods is provided in the [Supplementary Material 1](#).

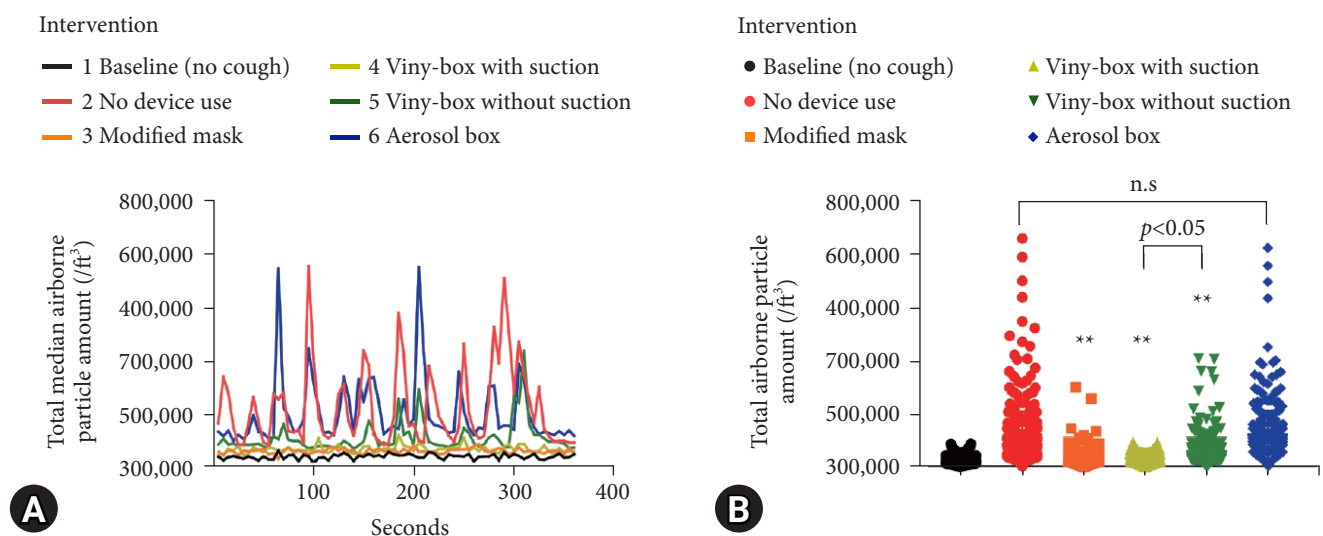
The total airborne amount during the simulation is shown in [Figure 2](#), as well as in [Table 1](#). The modified mask significantly reduced the total amount of airborne particles. The vinyl box with and without suction reduced the total amount of airborne particles, and using the suction significantly increased its effectiveness. There was no significant difference in the total amount of airborne particles between the aerosol box and control. Separate analyses for different particle sizes (0.3, 0.5, 1, and 2  $\mu\text{m}$ ) yielded similar results as the total airborne particles ([Supplementary Material 2](#)).

In this study, both the modified mask and vinyl box significantly reduced the exposure of the endoscopist to the total amount of airborne particles. In contrast, the aerosol box was ineffective. Furthermore, the adjunctive use of continuous suction with the vinyl box resulted in a significantly lower amount

of airborne particles than vinyl box use without suction. To the best of our knowledge, no prior studies have used an *in situ* simulation model to compare the effectiveness of various aerosol shielding devices in reducing endoscopist exposure to airborne particles during endoscopy.

The modified mask and vinyl box with continuous suction exhibited the most potent protective effect against exposure to airborne particles while maintaining the airborne particle amount at baseline levels. Among the tested devices, the modified mask provided the optimal coverage and closest adaptation to the mannequin's mouth. Its effectiveness highlighted the importance of sealing and covering the point of aerosol generation to minimize endoscopist exposure to airborne particles. Furthermore, the modified mask was the most simple, inexpensive, and easily disposable device among the tested masks. Its simple design also minimized the risk of interference with the endoscopic procedure. Therefore, the modified mask was the most practical, effective, and economical method to reduce endoscopist exposure to aerosol particles during the COVID-19 pandemic.

The aerosol box was the most commonly proposed aerosol shielding device. However, it provided no additional benefits compared to endoscopy without the use of a shielding device. Our results were similar to those of Simpson et al.,<sup>8</sup> who recently reported that the use of an aerosol box provided no



**Fig. 2.** Comparison of the total amount of airborne particles among the different experimental conditions. (A) Time series chart of each intervention over the 6 min experimental period. Lines represent the median total particle count (0.3–2  $\mu\text{m}$ ) of six separate trials. Coughs were generated every 30 seconds through the experimental period. (B) The number of total airborne particles during the simulation is shown on a scatter plot with medians and interquartile ranges.  $n=432$ . \*\* $p<0.01$  (versus no device use). n.s, not significant.

**Table 1.** Comparison of endoscopist exposure of total particles between four aerosol containment devices, no device use, and baseline

	Baseline	No device use	Modified mask	Vinyl-box with suction	Vinyl-box without suction	Aerosol box
Total particle amount	322,324 (313,711–332,993)	370,817 (350,303–433,071)	327,693 (334,670–342,485)	333,120 (327,103–337,072)	346,822 (340,451–355,023)	378,030 (361,893–396,436)
<i>p</i> -value comparing the medians among each group						
Baseline	-	<0.001	0.37	0.73	<0.001	<0.001
No device use	<0.001	-	<0.001	<0.001	<0.001	0.61
Modified mask	0.37	<0.001	-	0.99	0.08	<0.001
Vinyl-box with suction	0.73	<0.001	0.99	-	0.02	<0.001
Vinyl-box without suction	<0.001	<0.001	0.08	0.02	-	<0.001
Aerosol box	<0.001	0.61	<0.001	<0.001	<0.001	-

Values are presented as median (interquartile range).

protective effects against airborne particle exposure during simulated tracheal intubation. Dalli et al.<sup>9</sup> demonstrated that a significant amount of aerosol escaped from the arm access hole during simulated coughing. Although these studies involved simulated tracheal intubation, similar effects may be expected during endoscopic procedures. Aerosolized particle clouds escaped from the open side of the aerosol box during each simulated cough. Thus, shielding devices should be designed with smaller openings to reduce endoscopist exposure to airborne particles.

The vinyl box had a smaller opening than the aerosol box. This reduced the exposure to airborne particles. Continuous suction provided a significant benefit. The United States Food and Drug Administration recently issued an alert stating that the use of protective barrier enclosures without negative pressure increased the risk of COVID-19 infection in healthcare providers.<sup>10</sup> Our results supported the use of devices, such as the vinyl box, which had continuous suction to create a negative pressure effect within protective barriers.

Our study had several limitations. First, our simulation partially reproduced the actual endoscopy conditions. Further studies in clinical settings are needed to validate the protective effects of these aerosol shielding devices, especially those of modified masks and vinyl boxes (with continuous suction), against COVID-19 infection. Second, an increase in the quantity of airborne particles did not necessarily equate to a rise in viral infectivity during endoscopy. Despite numerous studies on the transmission routes of respiratory viruses, the relationship between these two variables remains vague. Third, the role of the upper GI tract in the transmission of severe acute respiratory syndrome coronavirus 2 remains unclear. Fourth, the devices evaluated in this study required the endoscopist to use personal protective equipment while performing endoscopic examinations. However, our results showed that some of these devices could contain almost all the generated airborne particles during simulated endoscopy. This suggested that using these devices allow endoscopists to perform endoscopy more safely than when using personal protective equipment alone.

In conclusion, this study demonstrated that the modified masks and devices with continuous suction effectively reduced endoscopist exposure to airborne particles during upper GI endoscopy. In contrast, both aerosol boxes and vinyl boxes (without suction) were ineffective.

## Supplementary Material

**Supplementary Material 1.** Supplementary material and methods.

**Supplementary Material 2.** *Post-hoc* comparisons of endoscopic exposure to each particle size under different experimental conditions.

Supplementary materials related to this article can be found online at <https://doi.org/10.5946/ce.2021.175>.

## Conflicts of Interest

The authors have no potential conflicts of interest.

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None.

## Author Contributions

Conceptualization: AH, YN, HM, YF; Data curation: AH, YN, HM; Formal analysis: AH; Supervision: YN, HM, YF; Writing-original draft : AH; Writing-review & editing: AH, YN, HM, YF.

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