Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Letter to the Editor

Aerosol spread with use of high-flow nasal cannulae: a computational fluid dynamics analysis

Sir,

Regarding the use of high-flow nasal cannulae (HFNC) in patients with coronavirus disease 2019 (COVID-19), although some researchers have claimed that HFNC are unlikely to contaminate the surroundings, others are strongly concerned about the risk of aerosol spread with HFNC [1,2]. Hui *et al.* [3] conducted a study with mannequins and claimed that aerosol spread does not increase if the HFNC is fitted properly to the face. However, Cheung *et al.* [4] pointed out that the HFNC modes and models in the study by Hui *et al.* differed from those in widespread use, and advised against the use of HFNC for patients with COVID-19. Leonard *et al.* [5] used computational simulation to show that wearing a surgical mask over the HFNC might reduce aerosol spread. However, keeping the mask fitted properly is a challenge; if the mask comes off, or slips aside, the aerosol may spread to the surroundings.

Aerosols enter the upper airway by opening and closing movements of the vocal cords during coughing and speaking [6]. It has been shown that nasal secretory cells are potential targets of severe acute respiratory syndrome coronavirus-2 [7]. Therefore, HFNC, which have a CO_2 wash-out effect, may wash out the viruses from the upper airway into the surroundings. To our knowledge, the distribution of particles in a room during spontaneous breathing (SB) with HFNC has not been analysed numerically to date. As such, we investigated aerosol dispersion during SB with and without HFNC using computational fluid dynamics (AcuSolve, Altair Engineering, Troy, MI, USA).

The analysis was performed in two steps: preliminary simulation (particle density of the exhaled air from the nostrils) and indoor air simulation (distribution of particles exhaled from the nostrils).

In the preliminary simulation, an upper airway and a nasal cannula were added to Kitaoka's four-dimensional (4D) lung model [8]. SB was simulated by a change in lung volume (tidal volume 0.4 L, respiratory cycle 4.0 s). The HFNC flow rate was set as 40 L/min. The airflow distribution in the airway was analysed by the arbitrary Lagrangian–Eulerian method, applying the moving boundary condition assigned by the 4D lung model during SB (nodes 120,573, time step 0.002 s). The air flow produced by SB passed in and out through the gap between the nostrils and the HFNC. The specified air flow (flow rate 40 L/min or 0 L/min) was sent constantly from the HFNC, and the excess air flow was discharged from the gap. Assuming a particle density in the upper airway wall of 100%, the particle density distribution in the airway was calculated by coupled analysis of Navier–Stokes and diffusion equations (diffusion coefficient 10^{-10} m^2/s) during breathing. In order to clarify the difference between HFNC and non-HFNC, the condition with the mouth closed was analysed. The result was that the average concentration of particles in the nostrils was approximately 58% without HFNC and 80% with HFNC. Furthermore, the total amount of particles discharged during one respiratory cycle was approximately 10 times higher with HFNC because the exhaled air volume through the nostrils was increased with high flow.

In the indoor air simulation, a three-dimensional model of a room (3.0 m×2.0 m×2.0 m) with ceiling ventilation, a bed and a human body on the floor was created. The human body was equipped with outlets imitating the nostrils. The same flow rate as in the preliminary simulation was used (SB ± HFNC).

In the first simulation, the particle concentration in the nasal cavity increased approximately 1.5 times with high flow. Although not supported experimentally, this result suggests that the particle concentration does not reduce due to dilution with high flow. Considering that the overwhelming flow rate of HFNC is added to the air flow from the nostrils, the effect of change in particle concentration in the exhaled air on the number of discharged particles can be ignored. Therefore, the second simulation was performed assuming that the particle concentration in the nostrils was 100% in simulations with and without HFNC.

The results are shown in the video (see online supplementary material). Aerosol spread was more extensive during SB with HFNC than during SB without HFNC, suggesting that medical staff may inhale aerosol after just 30 s at the bedside. In conclusion, when managing patients with COVID-19, we strongly recommend that HFNC should be avoided as much as possible; when HFNC are used, strict precautions against aerosol spread are necessary.

Supplementary video related to this article can be found at https://doi.org/10.1016/j.jhin.2020.06.010

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