Study on the Spread of COVID-19 Based on the Real Behavior of Emergency Room Personnel

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Abstract: Hospitals and other medical institutions are high-risk environments for the transmission of respiratory infectious diseases, such as COVID-19. This study analyzed a clinical skills competition conducted in the emergency department of a medical school in Hong Kong. Video data were collected of medical staff treating two categories of patients: P1 (critically ill) and P2 (agitated). A transmission model for respiratory infectious diseases was developed to assess the infection risk among healthcare workers and to evaluate the effectiveness of various preventive measures, using COVID-19 as a case study. Without mask protection, the hourly infection risk for treating P1 reached 43.4%, which was 3.1 times higher than the risk associated with treating P2. Wearing N95 and surgical masks throughout the entire treatment process reduced total infection risk by 93.3% and 49.4%, respectively. Based on real-world close contact scenarios, this study provides scientific evidence to inform targeted prevention and control strategies for respiratory infectious diseases in emergency medical settings.
***Keywords*:** doctor-patient behavior, hospital infection, emergency room, close contact, COVID-19

1. Introduction

Respiratory infectious diseases, such as COVID-19, continue to pose a significant threat to global public health. Among healthcare settings, emergency departments represent particularly high-risk environments due to their unique characteristics: high patient turnover, diagnostic uncertainty, and the urgency of clinical care.

Historically, numerous outbreaks have originated in emergency settings, leading not only to in-hospital transmission but also to broader community spread. SARS-CoV-1[1], MERS-CoV[2], and SARS-CoV-2 [3]. In 2015, the emergency department at Samsung Medical Center in Seoul became the epicenter of a major MERS-CoV outbreak, with 82 confirmed cases and a transmission rate of 20% among individuals in close contact with the index case[2]. Similar patterns were observed in SARS and COVID-19 outbreaks involving emergency department personnel and patients[1,3].

SARS-CoV-2 is highly transmissible[4], primarily spreading through close contact (short-range inhalation and facial mucous deposition) and through long-range airborne transmission[5,14]. Close contact behaviors, such as interpersonal distance and relative facial orientation, directly influence the risk of respiratory disease transmission[6]. The close contact between medical staffs and patients, along with high personnel mobility in emergency rooms, significantly increases transmission risk. However, empirical data on these factors in real emergency settings remain scarce due to ethical and logistical challenges — most notably, privacy concerns and the difficulty of obtaining informed consent during active patient care.

This study used video recordings from a clinical skills competition in a high-fidelity simulated emergency ward to systematically observe and quantify close contact behaviors — such as interpersonal distance, facial orientation, and exhalation-related activities — while maintaining patient confidentiality. Based on these data, we developed a comprehensive transmission model covering both close- and long-range airborne routes. Using COVID-19 as a case study, we assessed healthcare worker infection risk across patient types and evaluated the effectiveness of various non-pharmaceutical interventions (NPIs).

2. Methods

Close contact transmission is recognized as the primary route for the spread of COVID-19. According to definitions from the World Health Organization and the Centers for Disease Control and Prevention[7], close contact is typically defined as interpersonal interactions occurring at a distance of less than 1.5 meters. Key behavioral determinants of close contact transmission include interpersonal distance, relative facial orientation and exhalation activities such as talking and breathing (see Table 1).

Table 1. Definition of close contact behavior

Close contact behavior	Definition
Talk rate	Ratio of the talking time to the total recording time
Interpersonal distance	Distance between the noses of medical staff and patient
Relative facial orientation	Relative facial orientation between the faces of medical staff and patient (Figure 1b), including face-to-face (F-F), face-to-side (F-S), face-to-back (F-B), side of the infected (S-), and back of the infected (B-)
Mask wearing rate	Ratio of the mask wearing time to the total recording time

3. Data collection

We obtained video recordings from a clinical skills competition held at a medical school of a university in Hong Kong, comprising a total of 19,246 seconds of footage capturing medical staff interacting with patients in a simulated emergency room setting. This study focused specifically on close contact behaviors between patients, doctors, and nurses, with detailed observations and recordings of their interactions. The simulation included two types of patients: P1 (Critically ill patient): Represented by a manikin, whose primary treatments involved chest compressions and endotracheal intubation. P2 (Agitated patient): Played by a real person, whose care involved assisting after a fall, emotional calming, and monitoring of vital signs.

The video footage was organized into six groups. Each group consisted of three doctors (including one attending physician and two general physicians), two nurses, and two patients. Notably, the attending doctor was the same individual across all six video groups, ensuring consistency in the role of lead medical staff. For Patient 1 (P1), who was in critical condition, both doctors and nurses actively participated in emergency interventions. These included the use of medical equipment and coordinated efforts to perform chest compressions. For Patient 2 (P2), who was agitated and had experienced a fall, all doctors and nurses responded by approaching the patient, offering verbal reassurance, and assisting him back to the bed for rest. Nurses were responsible for securing the patient with a safety belt and providing emotional support, while doctors recorded the patient's condition and occasionally assisted nurses when needed. Throughout the entire process, the attending physician played a supervisory and supportive role, guiding the team in clinical decision-making and procedural execution.

The dimensions of the emergency room are 13.0 × 10.0 × 2.8 m. There are four fixed cameras in the room (Figure 1), and all personnel are captured by at least two cameras, avoiding the problem of occlusion in a single video at some angles.

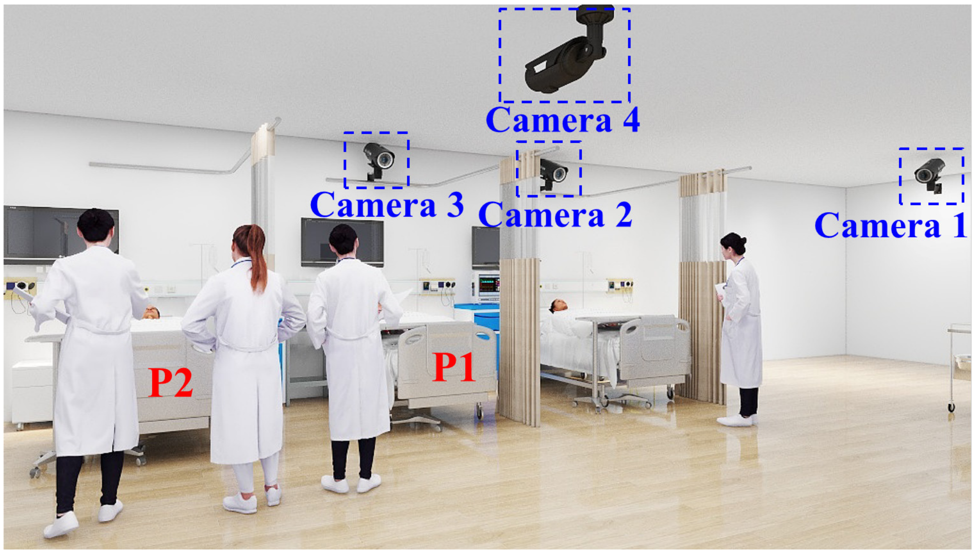

Figure 1. Emergency room layout and camera location

Six trained students conducted a frame-by-frame analysis of the video recordings, reviewing the footage second by second. To ensure the accuracy and consistency of the observations, the standard dimensions of hospital beds and other fixed items in the emergency room were measured prior to the analysis. These measurements were used as reference points to estimate the interpersonal distances between individuals[8].

The final data were cross-checked by a video analyst (first author) every 6 minutes, and a total of 2,200 data points were reviewed, yielding an accuracy rate of 95.1%.

4. Exposure calculation

4.1 Close contact transmission

We considered two respiratory activities responsible for aerosol generation: breathing and talking. The infected individual was assumed to be an asymptomatic COVID-19 patient who continuously emits virus-laden aerosols during these activities. Given the significant variation in viral concentrations across aerosol particle sizes[9], exhaled aerosols were categorized into two groups: fine particles (≤5 μm) and large particles (>5 μm). Fine particles generated by breathing were assumed to release the virus at a rate of 4.5×10^{-2} viral RNA copies per second. Talking produced fine aerosols at a rate of 1.0 viral RNA copies per second, while large-particle aerosols generated during speech were emitted at a rate of 7.4×10^{-2} viral RNA copies per second.

Based on the above human behavior and virus production characteristics, the exposure rate (viral RNA copies/s) of short-range inhalation (e_s) and facial mucous deposition (e_m) of susceptible person i can be calculated as follows:

$$e_s(i,s,d) = G_t(j,s)\cdot\eta_{d,s}(s)\cdot\varphi_t\cdot\eta_{f,s}(s) + G_b(j,s)\cdot\eta_{d,s}(s)\cdot(1-\varphi_t)\cdot\eta_{f,s}(s) \quad (1)$$

$$e_m(i,s,d) = G_t(j,s)\cdot\eta_{d,m}(s)\cdot\varphi_t\cdot\eta_{f,m}(s) + G_b(j,s)\cdot\eta_{d,m}(s)\cdot(1-\varphi_t)\cdot\eta_{f,m}(s) \quad (2)$$

In the model, i and j represent a susceptible individual and an infected individual, respectively. d denotes the interpersonal distance between them. Aerosol particle size, denoted as s , is classified into two categories: fine particles (≤5 μm) and large particles (>5 μm). $G_b(j,s)$ and $G_t(j,s)$ represent the viral RNA emission rates (viral RNA copies/s) in aerosols of particle size s , generated by infected individual j through breathing and talking, respectively. φ_t indicates the speaking rate during close contact, based on video analysis, P1 was intubated and thus assumed to have a speaking rate of 0, while P2 exhibited a speaking rate of 65.4%. Critically ill patients are known to have significantly higher viral loads, with an average approximately 60 times greater than that of non-critical patients (Liu et al., 2020). Accordingly, the viral emission rates from Patient 1 during breathing and talking were scaled by a factor of 60. We defined the following attenuation coefficients: $\eta_{d,s}(s)$ and $\eta_{d,m}(s)$: distance attenuation coefficients for aerosol inhalation and facial deposition, respectively. These are calculated as the ratio of the exposure rate at a given distance to the viral emission rate of the infected individual. $\eta_{f,s}(s)$ and $\eta_{f,m}(s)$: facial orientation attenuation coefficients for inhalation and facial deposition, respectively. These are defined as the ratio of the exposure rate at a given facial orientation to the rate at direct face-to-face orientation at the same distance[10] . Both sets of attenuation coefficients were derived from computational fluid dynamics (CFD) simulations[11].

4.2 Effect of masks on exposure

This study evaluated the impact of N95 respirators and surgical masks on reducing respiratory pathogen transmission. Based on prior research[12], the inward protection efficiencies against fine aerosols were 91.7% for N95s and 52.4% for surgical masks; outward efficiencies were 94.2% and 64.2%, respectively. Both masks were assumed to fully filter large particles (100%). The close-contact exposure rate e_M was then calculated by integrating these efficiencies across particle sizes and mask types.

$$e_M = V_E\cdot(1-\rho_{out})(1-\beta\cdot\rho_{in}) \quad (3)$$

Where ρ_{in} and ρ_{out} are the inward and outward protection efficiencies respectively; β is the mask wearing rate.

5. Infection risk assessment

Due to the lack of specific dose-response parameters for SARS-CoV-2, this study adopted a proxy approach by referencing parameters from SARS-CoV-1, a genetically and clinically similar virus [13]. This assumption is commonly used in infection risk modeling where empirical data for the target pathogen are limited.

The dose-response model developed by Watanabe et al.[15] (Watanabe et al. 2010) has been shown to effectively predict the infection risk of SARS-CoV-1. Therefore, in this study, this model was applied to estimate the infection risk (R) associated with SARS-CoV-2 exposure. Accordingly, the infection risk can be calculated using Formula 4:

$$R = 1 - exp\left(-\frac{E_s}{k_s} - \frac{E_m}{k_m}\right) \quad (4)$$

Where, E_s and E_m represent the viral exposure per hour (in viral RNA copies) due to short-range inhalation and facial mucosal deposition, respectively. k_s and k_m are the corresponding dose-response thresholds for infection via these two exposure pathways.

Based on prior studies[13], the initial dose-response thresholds were set as k_s = 4.065 RNA copies for inhalation and k_m = 406.5 RNA copies for mucosal deposition. However, given concerns that this ratio may underestimate the relative infectivity of inhalation exposure, we adjusted the ratio of k_s to k_m to 1:10 in this study. Accordingly, k_s and k_m were set to 40.65 and 406.5 RNA copies, respectively.

6. Results

6.1 Close contact behaviors

The average interpersonal distance between nurses and patients (0.89 m) was slightly smaller than that between doctors and patients (0.95 m) (Figure 2). During close contact with patients, doctors and patients primarily had face-to-face (F-F) contact (40.4%). In contrast, nurses and patients mostly had side contact (39.3%), and face-to-back (F-B) contact was rare (0.1%). Throughout the treatment of both P1 and P2, the face-to-face contact ratio between doctors and patients was consistently higher than that between nurses and patients, with ratios 1.4 times and 2.0 times greater for doctors, respectively. This difference may be due to doctors needing to observe patients for extended periods and document their conditions.

1.0 (25-75 percentile:0.8, 1.2) m for P1 patients and 0.5 (0.4, 0.7) m for P2

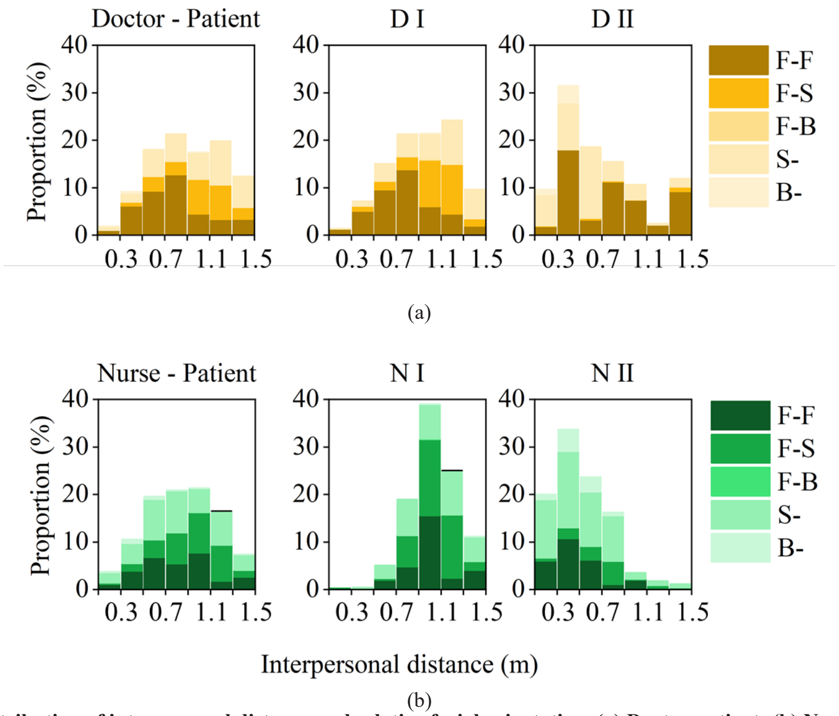

Figure 2. Probability distribution of interpersonal distance and relative facial orientation. (a) Doctor-patient; (b) Nurse-patient. (The leftmost one in Figures ab is the average value, F-F means face-to-face, F-S means face-to-side, F-B means face-to-back, S- means side of the infected, and B- means back of the infected)

6.2 Infection risk

When medical staff did not wear masks, the average hourly infection risk in the emergency room was 22.0%. Specifically, the hourly infection risks for treating Patient 1 (P1) and Patient 2 (P2) were 43.4% and 13.9%, respectively(Figure 3). The infection risk when treating P1 was the highest (43.4%), which was 3.1 times greater than that for P2. For P1, there was no significant difference in infection risk between doctors and nurses ($p > 0.05$). However, when treating P2, nurses faced a 1.5 times higher infection risk compared to doctors. This difference may be attributed to the need for medical staff to assist patients closely, with nurses being more directly involved in supporting the patients, thus reducing the interpersonal distance.

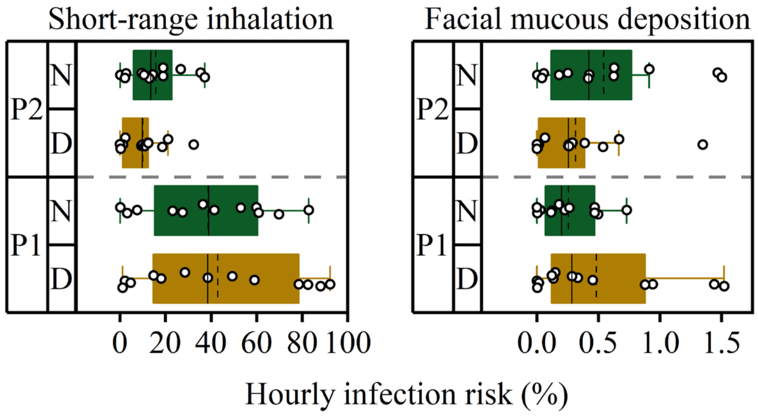

Figure 3. Probability distribution of interpersonal distance and relative facial orientation. (a) Doctor-patient; (b) Nurse-patient. (The leftmost one in Figures ab is the average value, F-F means face-to-face, F-S means face-to-side, F-B means face-to-back, S- means side of the infected, and B- means back of the infected)

6.3 The protective effect of masks

If all medical staff wear N95 masks, the total hourly infection risk can be reduced by 93.3% (Figure 4). Specifically, the risks of infection via inhalation and mucosal deposition are reduced by 93.3% and 94.5%, respectively. In comparison, if all medical staff wear medical surgical masks, the total hourly infection risk is reduced by 49.4%.

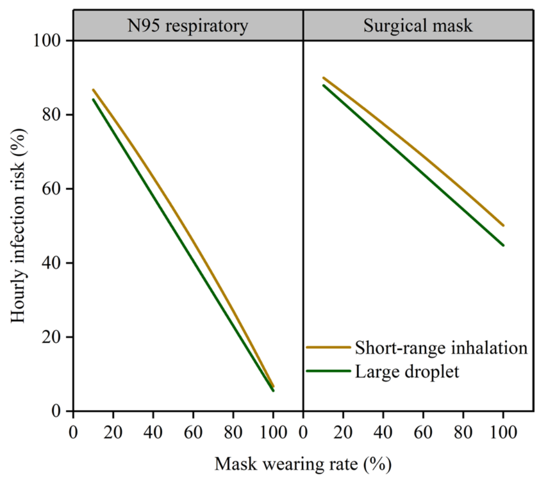

Figure 4. Relationship between mask wearing rate and infection risk

7. Discussion

Based on video footage from the emergency department of a medical school in Hong Kong, this study analyzed close contact behaviors between medical staff and two types of patients — critically ill (P1) and agitated (P2). Using COVID-19 as a representative pathogen, a real-world transmission model was developed to evaluate infection risks and the effectiveness of various non-pharmaceutical interventions (NPIs) under different treatment scenarios.

Interpersonal distance plays a key role in transmission risk — contact at 0.4 m poses significantly higher risk than at 2 m[16]. In this study, the average interpersonal distance was 1.01 m for P1 and 0.61 m for P2, both shorter than China's general social distance of 1.2 m. Notably, during P1 treatment, doctors maintained a shorter distance (0.97 m) than nurses (1.07 m), underscoring their primary role in critical care interventions. Facial orientation was also a critical factor: face-to-face interactions posed significantly higher exposure risks[11]. The highest probability of face-to-face contact (42.5%) occurred during P1 treatment, with doctor-patient face-to-face contact reaching 52.8%, compared to 26.0% for nurses.

Given that maintaining safe distances and avoiding face-to-face contact is often unfeasible in emergency settings, personal protective equipment becomes vital. Wearing an N95 mask can reduce infection risk by 93.3%, while surgical masks offer a 49.4% reduction. However, mask leakage may compromise protection[17], underscoring the importance of proper mask fit. Additionally, in certain procedures — particularly involving agitated patients—nurses faced higher infection risks than doctors, indicating a need for targeted protective strategies.

This study has several limitations. First, it only modeled patients as the infection source, excluding staff-to-staff transmission. Second, some interactions used manikins, and data from a clinical skills competition may limit ecological validity. Third, the model assumed complete air mixing for long-range aerosol transmission, potentially introducing bias. Future work should use real emergency room footage and experimental validation (e.g., gas markers) to improve model accuracy and relevance.

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