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# Comparison of hand contamination rates and environmental contamination levels between two different glove removal methods and distances

Joanna Y.F. Lai, MS,<sup>a</sup> Y.P. Guo, PhD,<sup>b</sup> Peggy P.L. Or, MS,<sup>a</sup> and Yi Li, PhD<sup>b</sup>  
Hong Kong, China

**Background:** Gloves are a necessary contact precaution to prevent transmission of infectious pathogens that spread by direct or indirect contact with an infected person or a contaminated environment. This article reports a study investigating hand and environmental contamination levels when health care workers (HCWs) followed two different methods of removing gloves at two distances from the rubbish bin.

**Methods:** Fifty HCWs performed a personal or causal glove removal method (pretest) and a Centers for Disease Control (CDC)-recommended glove removal method (posttest) at distances of 2 feet and 3 feet from the rubbish bin after the application of fluorescent solution (the simulated contaminant) onto their gloved hands.

**Results:** The incidence of the small patch of fluorescent stain (<1 cm<sup>2</sup>) on the front of the doffed gloves was significantly lower in the posttest than in the pretest. The incidence of small and large patches (>1 cm<sup>2</sup>) on the front of the doffed gloves and on the cover of the rubbish bin was significantly lower at 3 feet than at 2 feet. Health care assistants had significantly higher levels of contamination than other HCWs in the pretest but not in the posttest. There was no significant difference in hand contamination rate between pretest and posttest based on distance from the rubbish bin and type of HCW.

**Conclusion:** The impact of the glove removal procedure and the distance to the bin in which used gloves are discarded should be taken into consideration on a daily basis, along with the supervision of infection control measures by minor staff.

**Key Words:** Health care worker; infection control; glove doffing; fluorescent stain; training and supervision.

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The consequences of bioterrorism and the threat of emerging infectious diseases, such as smallpox, severe acute respiratory syndrome (SARS), and a recent new type of influenza A (H1N1), have become a reality for frontline health care workers (HCWs).<sup>1-6</sup> The use of personal protective equipment (PPE) is recommended for optimal protection from cross-infection among patients and other HCWs.<sup>3-7</sup> Gloves are not only necessary for contact precautions, but also essential for preventing the transmission of infectious bacteria, viruses, and microorganisms that can spread by direct or indirect contact with an infected person or contaminated environment.<sup>7-9</sup> Gloves also reduce the

transmission risks posed by the presence of excessive wound drainage, fecal incontinence, or other bodily discharges.<sup>10</sup>

Despite the recommendations, the risk of health care-associated infection through transmission of microorganisms from contaminated gloves to HCWs' hands remains, however.<sup>11-13</sup> Pittet et al<sup>14</sup> and Boyce<sup>15</sup> reported finding bacteria from patients on the hands of 30% of HCWs who had worn gloves for each patient contact. Pittet et al<sup>14</sup> found that HCWs who wore gloves during patient contact experienced hand contamination at an average rate of 3 colony-forming units (CFU) per minute of patient care. Bacteria and viruses can be passed to HCWs' hands through gloves or by contamination of hands during glove removal.<sup>12,16-19</sup> The possibility of contamination considerably increases the potential risk to HCW's hands, which can become infected by contact with a glove at the time of removal. In addition, because latex gloves are elastic and stretchable, certain areas of a working environment might be contaminated by the stretching motion during glove removal.<sup>20</sup> Thus, unpredictable contamination could stain the clinical environment. Most previous studies have identified hand contamination<sup>9,21</sup> and the

From the School of Nursing<sup>a</sup> and Institute of Textiles and Clothing,<sup>b</sup> Hong Kong Polytechnic University, Hong Kong, China.

Address correspondence to Yi Li, PhD, Institute of Textiles and Clothing, Hong Kong Polytechnic University, Hung Hom, Kowloon, Hong Kong, China. E-mail: [tclyi@polyu.edu.hk](mailto:tclyi@polyu.edu.hk) or [tclyi@inet.polyu.edu.hk](mailto:tclyi@inet.polyu.edu.hk).

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permeable effect of gloves<sup>22,23</sup> as problematic; however, few studies have explored the possible environmental contamination caused by the stretching motion during glove removal.

Recent studies noted that some HCWs became infected with SARS despite wearing full PPE (gloves, gown, and N95 respirator).<sup>2,24,25</sup> This “through precautions” transmission might be caused by contamination during the removal of protective clothing.<sup>26,27</sup> A study examining self-contamination rates in HCWs wearing two personal protective systems found that the anterior neck, forearms, wrists, and hands were the likeliest zones for contamination during removal of protective systems.<sup>28</sup> This points to the importance of properly removing PPE, including gloves, which may minimize self-contamination, contamination of the working environment, and possibly contamination of patients.

The Centers for Disease Control and Prevention (CDC) has recommended a PPE doffing method for removing gloves since the SARS attack in 2003.<sup>29</sup> To minimize contamination during the removal of contaminated gloves, the focus must be on the doffing method used. However, to date no studies have examined the effects of the CDC-recommended method on the preventing contamination by comparing the contamination rates associated with the CDC’s glove removal method and personal or causal glove removal methods (ie, those predominately used in daily practice). Given the vital need to prevent contamination from gloves, this study had 2 purposes. The study set out to examine the hand contamination rates and environmental contamination levels when (1) different methods of glove removal were followed, including personal or causal methods (pretest) and the CDC’s recommended method (posttest), and (2) the distance to the bin varied between 2 feet and 3 feet (customary distances used by HCWs in Hong Kong), measured in the common gown down areas (ie, designated areas for HCWs to gown down their PPE) in the fever and cohort wards (wards for patients with epidemiological and clinical information suggestive of a similar diagnosis to share rooms, and with a spatial separation of at least 1 meter from one another) of a public hospital in Hong Kong. In the posttest, all of the subjects had to follow the CDC’s glove removal steps. For the pretest, subjects could remove gloves however they wished, which differed considerably from the CDC method. We hypothesized that (1) different methods of glove removal have different effects on hand contamination rates and environmental contamination levels; (2) contamination levels differ between the 2 foot and 3 foot distances from the rubbish bin; and (3) following the CDC’s glove removal method may significantly decrease contamination of HCWs and the environment.

**Table 1.** Demographic data for the study participants (n = 50)

Characteristic	Value
Age, mean ± SD (range)	31.9 ± 8.4 (20-52 years)
Working experience: HCA, RN/EN, and NO/APN, mean ± SD (range)	7.0 ± 7.3 (1-30 years)
Preworking experience: TUNS	2.0 ± 0 (years)
Sex, n	
Male	8 (16%)
Female	42 (84%)
Total	50 (100%)
Rank and departmental representation, n	
HCA (isolation)	4 (8%)
RN/EN (isolation, medical, pediatric, outpatient clinic)	30 (60%)
NO/APN (isolation, medical, accident and emergency)	6 (12%)
TUNS	10 (20%)
Total	50 (100%)

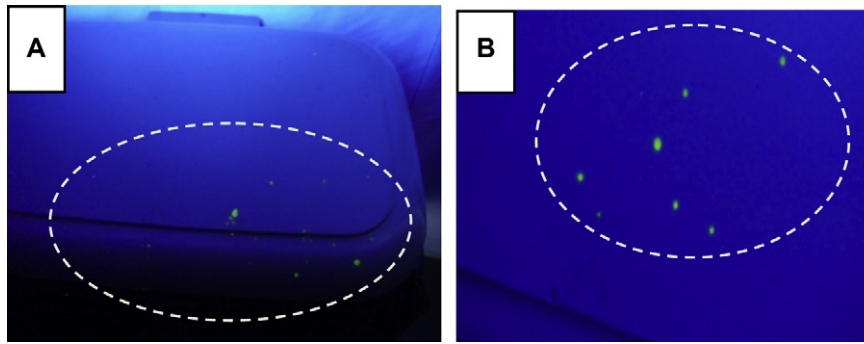
HCA, health care assistant; RN/EN, registered nurse/enrolled nurse; NO/APN, nursing officer/advanced practice nurse; SD, standard deviation; TUNS, temporary undergraduate nursing student.

## METHODS

### Subjects

A total of 50 subjects were invited to participate in this study, including 42 females (nurses and health care assistants) and 8 males (nurses). All participants were recruited from a 1,800-bed acute care hospital in Hong Kong, but although we used a convenience sampling method and attempted free sequencing, the sequence was not by randomization. Reflecting the female predominance in the nursing profession, 84% of the subjects were female and 16% were male. The study included 10 temporary undergraduate nursing students (TUNSS) who had more than 2 years prework experience (ie, a job working in the hospital before promotion to nursing staff) in different departments, including 4-month rotations in surgical, medical, pediatric, orthopedic, neurosurgical, and accident and emergency departments. In addition to the TUNSS, the sample included 4 health care assistants (HCAs), 30 Registered Nurses (RNs) or enrolled nurses (ENs), and 6 nursing officers (NOs), including advanced practice nurses (APNs). Because each subject completed the experiment on the same day, the response rate was 100% in this study. Two subjects performed the same glove removal method in the pretest and posttest and were replaced by two subjects who followed the specified processes. The total sample size was 50. The subjects’ demographic data are summarized in Table 1.

Ethics approval was applied for before the study began, and the experimental protocol was approved by the Human Subjects Ethics Subcommittee of the Hong Kong Polytechnic University before the start of



**Fig 1.** FPs on the edge of the rubbish bin cover (A) and on the rubbish bin cover (B).

the experiment. Each subject provided written informed consent before taking part in the study and after being familiarized with the study's nature, purpose, method, and risks. All subjects were volunteers and could withdraw at any time without any reason. Confidentiality and anonymity were ensured. The study was completed on the same day, with no subjects returning for follow-up, and no dropouts were noted.

### Gloves

Disposable latex gloves were used for the test, because latex is the material generally used by Hong Kong Hospital Authority (HKHA). Powder-free latex gloves (Saf-Care PLUS; Careplus (M) Sdn Bhd, Seremban, Negeri Sembilan, Malaysia) were purchased from the HKHA's supplier. Powder-free latex gloves carry less risk of leakage compared with vinyl gloves.<sup>22,23</sup> Each subject selected the glove size (small, medium, or large) that he or she uses daily and examined the integrity of the glove by manual checking. After the glove integrity was double-checked by the researcher, the fluorescent solution was applied. No leakage or reuse of gloves was allowed, because this might have affected the contaminated fluorescent patch (FP).

### Fluorescent solution

Yellow fluorescent organic dye is used in angiography for the diagnosis and categorization of vascular disorders.<sup>30</sup> Many studies use fluorescent stain to represent the contamination caused by pathogens.<sup>28,31-33</sup> Following Zamora et al,<sup>28</sup> a contamination stain larger than 1 cm<sup>2</sup> was considered a large patch, and one smaller than 1 cm<sup>2</sup> was considered a small patch. Figure 1 shows some FPs detected on the edge of the rubbish bin cover and on the cover itself.

The fluorescent solution was diluted from 20 g of free acid fluorescent dye (F2456 free acid dye; Sigma-Aldrich Chemil GmbH, Munich, Germany) into a 1 M sodium hydroxide solution (Fixamal; Sigma-Aldrich Chemil GmbH) to form a water-soluble solution of

fluorescent sodium. Once the product was completely dissolved, 2 L of water was added to form a suspension. For the study, 5 mL of the fluorescent solution was sprayed on each gloved palm (a total of 10 mL on both palms) (Fig 2). As mentioned earlier, fluorescent dye is not known to be harmful to the human body and can be injected into veins in a fundus fluorescein angiogram to safely and effectively diagnose eye problems.<sup>31</sup> In the present study, the final fluorescent solution applied to on each gloved palm was similar to that used in fundus fluorescein angiography (0.05 g/5 mL).<sup>31</sup> The subjects were instructed to repeat the following procedure 5 times: pull back a plunger to fill a bladder wash syringe with 60 mL of air and then expel all 60 mL of air. This procedure was considered a common simulation of a simple daily nursing procedure, such as a Ryle tube feeding or bladder washout. This simple procedure was completed before doffing gloves.

Three large pieces of white cloth were placed onto the wall in front of and on both sides (left and right) of the subject. The white cloth was intended to clearly show the FPs. Due to the difficulty in counting the small patches, the researcher drew a grid (30 cm<sup>2</sup> squares) on all white cloths to facilitate the counting in each individual grid.

### Ultraviolet lamp

The ultraviolet (UV) lamp (Stylish 12" fluorescent lantern; John Manufacture Ltd; Hong Kong, China) is useful for detecting FPs, making the invisible stained patch visible. The UV lamp was checked and tested before the study; the same brand of UV lamp was used throughout the study period, to prevent any significant mismatch in the results. All participants assessed the UV lamp before donning the gloves and protective clothing to ensure that no fluorescent solution was present.

### Timing

The researcher recorded the time taken for glove removal in the pretest and posttest periods.



**Fig 2.** Fluorescent solution (10 mL) sprayed on a subject's palms.

### Study procedures

In brief, in an experimental laboratory (ambient temperature, 22~25°C; relative humidity, 70%), each of the 50 subjects completed the pretest and posttest glove removal at two separate sessions separated by a 30-minute interval after 10 mL of the fluorescent solution was sprayed on both palms. A video demonstrating the CDC's recommended glove removal method was shown between two sessions. After glove removal, FPs were counted by a UV scan under dim light. Skin testing for allergy to fluorescent dye was performed before the testing to exclude any subject with an allergy and avoid the risk of an allergic reaction. Figure 3 shows the procedural sequence.

### Statistical analysis

All data were analyzed using SPSS 17.0 for Windows (SPSS Inc, Chicago, IL). Descriptive statistics were used for all independent variables, including subjects' sex, age, rank, and work experience. A repeat measurement was made to compare the results of the CDC glove doffing method at two different distances (2 feet and 3 feet) between the subject and the rubbish bin. Hotelling's  $T^2$  test of multivariate analysis was used to identify any significant differences in contamination of the front white cloth between the pretest and the posttest. One-way analysis of variance was applied to the data to compare the sample means of ranking of staff and the time of glove removal. When a significant difference for a main effect was obtained, the multiple-comparisons method of Bonferroni was used to identify specific differences. All reported differences were considered significant at  $P < .05$ .

## RESULTS

### Pretest and posttest

Figure 4A shows the small patches of fluorescent stain on the front of the cloth for the pretest and posttest. There were significantly fewer small patches in the posttest than in the pretest ( $P < .05$ ), suggesting that the CDC glove removal procedure reduced the number of small patches. No significant differences were noted in other contamination stains of different sizes and at different sites.

### Differing distances

Table 2 shows the level of contamination at 2 feet and 3 feet from the rubbish bin. There were significantly fewer small patches on the front of the cloth and on the cover of the rubbish bin at 3 feet than at 2 feet ( $F = 12.8, P < .001$  and  $F = 19.6, P < .001$ , respectively), averaging 11.8 and 7.8, respectively, for the pretest and 3 and 2.9 for the posttest. Similarly, there were significantly fewer large patches on the front of the cloth and the cover of rubbish bin at 3 feet than at 2 feet ( $F = 11.3, P = .001$  and  $F = 3.9, P < .05$ , respectively), averaging 0.2 and 0.1 for the pretest, and 0.16 and 0.2 for the posttest. As shown in Table 2, the small patches were more common than the large patches.

### HCW ranking

Figure 4B shows HCW rankings for the small patches on the front of the gown at pretest and posttest. Significant differences among HCW rankings can be seen in the pretest ( $F = 4.08, P = .01$ ). HCAs had significantly higher levels of contamination compared with RNs, ENs, and TUNSSs. However, there was a significant improvement in the rate of contamination after the CDC glove removal demonstration, with no significant differences among different types of staff seen in the posttest.

### Timing

On an average, subjects removing gloves following the CDC glove removal method required 10.9 seconds (range, 6-23 seconds), whereas those removing gloves following a personal or causal doffing required only 6.1 seconds (range, 2-12 seconds;  $F = 145.3; P < .001$ ) (Fig 5). There were no significant differences in hand contamination rate between the two groups in terms of pretest and posttest, distance, and HCW ranking.

## DISCUSSION

This study shows that glove removal induces contamination of the environment. At 2 feet from the rubbish bin, we detected small patches of fluorescent stain

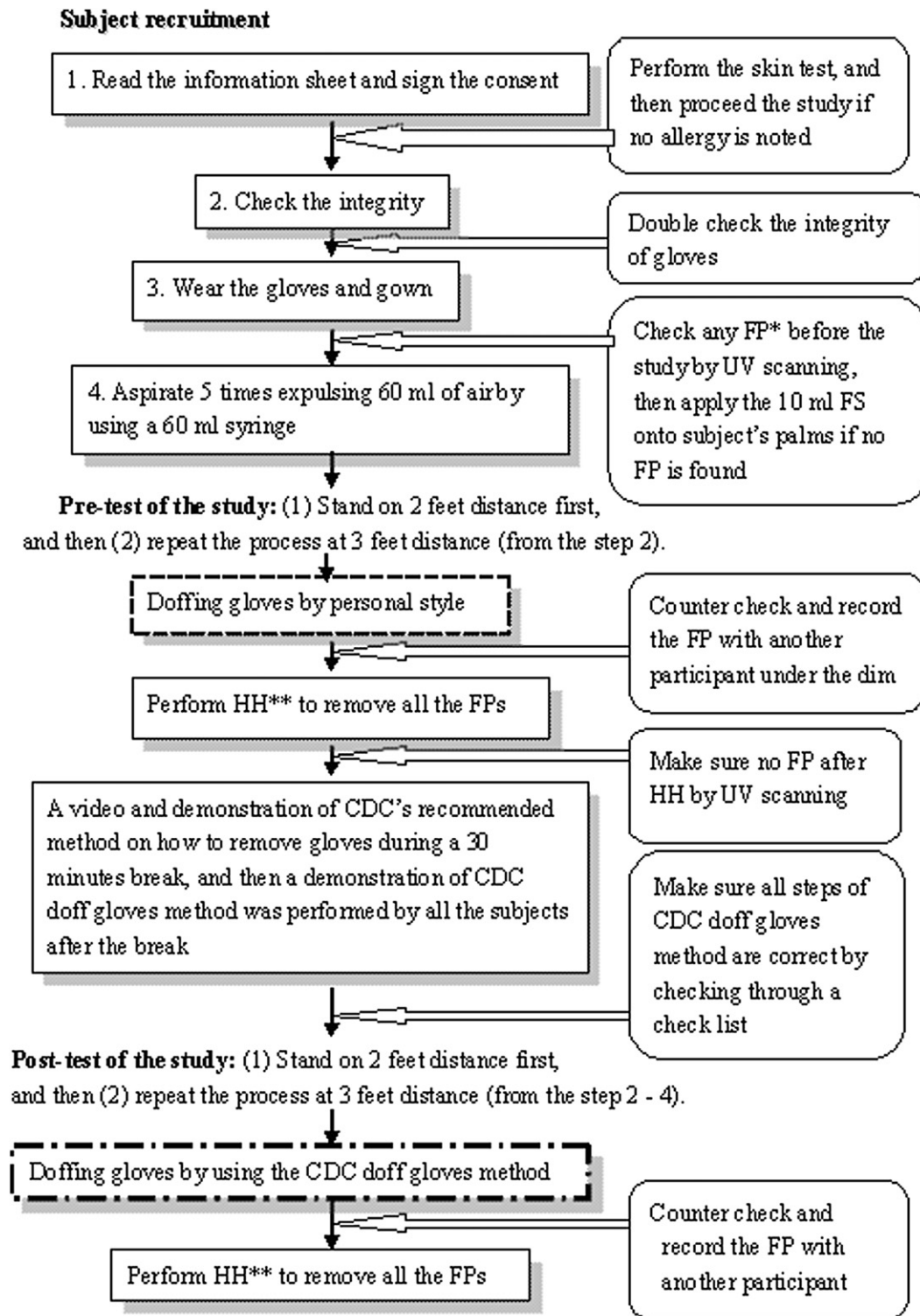
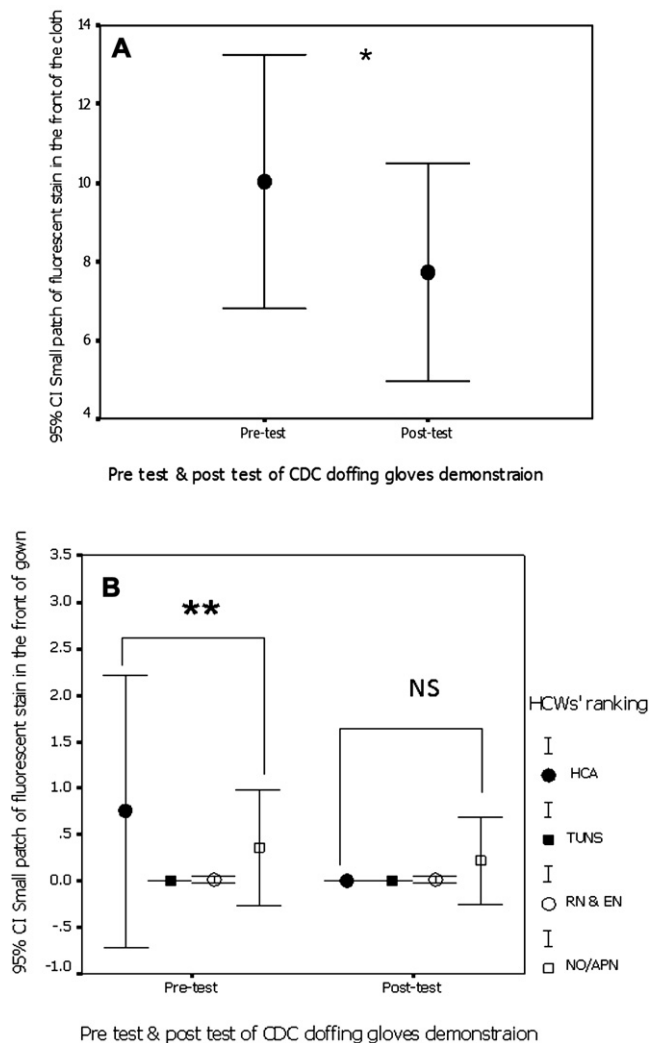


Fig 3. Flowchart of the study procedure.



**Fig 4.** Small patches of fluorescent stain (A) and HCW rankings (B) on the front of the cloth for pretest and posttest of the CDC glove removal demonstration. NS, not significant. \* $P < .05$ ; \*\* $P = .01$ .

after the two glove removal methods, an average of 15.9 and 10.3 patches for the pretest and 9.2 and 6.7 for the posttest. At 3 feet, the number of these patches was reduced significantly, from 11.8 and 7.8 for the pretest to 3 and 2.9 for the posttest. Significantly fewer large patches were found, averaging 0.1-0.2 patch at 2 feet and virtually 0 at 3 feet. These findings might imply the following potential mechanisms for transmission of diseases spread by glove removal: (1) Glove removal mainly induces environmental contamination, especially on the front of removed gloves and the cover of rubbish bin, rather than hand contamination. (2) Contamination levels differ between the 2-foot and 3-foot distances from the rubbish bins (the former

is higher). The environmental contamination would be greatly reduced by increasing the distance by about 1 foot when discarding used gloves. And (3) small patches are the more frequent form of contamination. Our findings support the validity of our first two hypotheses proposed earlier in the article.

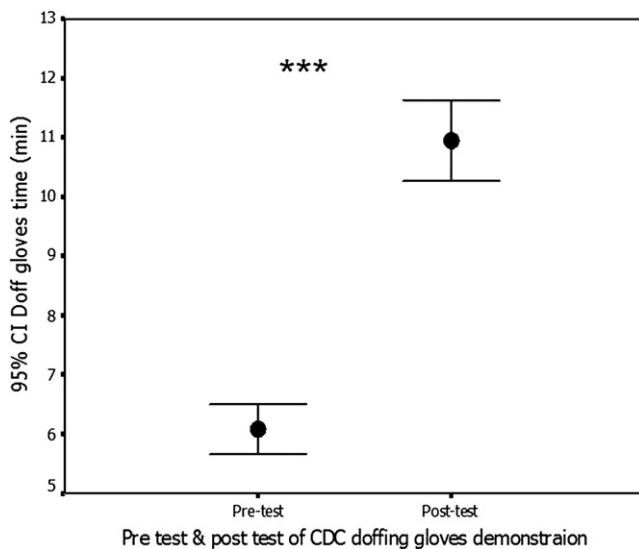
Our results also verify the third hypothesis as well. There were significantly fewer small patch of fluorescent stain on the front of the cloth and on HCA's gowns after the CDC glove removal demonstration. These observations show that the CDC glove removal method significantly decreased the rate of contamination of the environment and HCWs, indicating that the CDC recommendations can help eliminate contamination of the area between the HCW and the environment. These findings need to be shared with HCWs to emphasize the importance of evidence-based practice to their daily practice. Most HCWs have learned the CDC glove removal steps after the SARS outbreak of 2003, and many attend infection control lectures periodically to refresh their practice. Nonetheless, some of the subjects had forgotten the CDC glove removal steps before watching the video for this study. Our hospital has many posters reminding frontline HCWs about hand hygiene and the sequence for removing PPE, yet none of these HCWs followed the CDC glove removal procedure. As far as the results of this study are concerned, the CDC glove removal procedure is certainly essential to prevent cross-infection in daily practice. Thus, we recommend posting related information and continue reminding HCWs about infection control measures through lectures, talks, pamphlets, posters, and supervisory interactions.

Previous studies have focused mainly on either hand contamination<sup>34,35</sup> or contamination of other PPE components.<sup>8,9,12,14,28,31-33</sup> Limited research has explored environmental contamination due to the stretching action of removing gloves. Our data fill this research gap and suggest many helpful implications for infection prevention and control. Our findings suggest that HCWs should avoid standing in front of a patient, other HCWs, or clean areas such as the nursing station while removing gloves. Such measures may be included in the usual infection control measures that facilitate the prevention of cross-infection and environmental contamination. Likewise, the placement of the rubbish bin is also an important point, given that most HCWs remove their gloves in front of the bin. We recommend not placing the rubbish bin under the sink used for hand hygiene. Standing in front of the sink while removing gloves could result in contamination of the edge of the sink. Contamination and recontamination on the front side of their working clothes also might occur when HCWs approach the sink for hand hygiene afterward. Thus, we recommend that

**Table 2.** Level of contamination at distances of 2 and 3 feet

CDC doff gloves demonstration		Small patch: number of stains in the front of the cloth		Small patch: number of stains on the cover of rubbish bin		Large patch: number of stains in the front of the cloth		Large patch: number of stains on the cover of rubbish bin	
		2 feet	3 feet	2 feet	3 feet	2 feet	3 feet	2 feet	3 feet
Pretest	Mean	15.9	4.1	10.3	2.5	0.2	0.0	0.1	0.0
	SEM	2.8	1.0	1.8	0.4	0.1	0.0	0.05	0.0
Posttest	Mean	9.2	6.2	6.7	3.8	0.2	0.04	0.2	0.0
	SEM	2.3	1.5	1.1	1.0	0.1	0.03	0.2	0.0

SEM, standard error of the mean.



**Fig 5.** Glove removal times for the pretest and posttest periods. \*\*\* $P < .001$ .

the rubbish bin be placed at least 2 feet away from the sink.

In this study, HCAs had a significantly higher level of contamination compared with RNs, Ens, and TUNs in the pretest period. HCAs might lack systemic knowledge of nursing science, especially in the area of infection control because they were only trained for 1 month in such basic nursing procedures as measuring urine output, emptying urine bags, providing tube feedings, and changing napkins before they were employed. Their use of a personal or causal glove removal procedure in their daily practice might have led to higher rate of environmental contamination. This findings indicates that minor staff should pay more attention to infection control as an essential part of their daily practice, and that closer supervision should be provided. The HCAs did demonstrate decreased environmental contamination after viewing the CDC glove removal video and demonstration; therefore, there were no

differences in ranking in the posttest period. This finding supports the importance of training and supervision for minor staff on proper glove removal.

Although the CDC method offers superior protection against environmental contamination, it takes longer, likely due to rusty technique. It is conceivable that more trainings and practice exercises will decrease the time required for glove removal.

In summary, more contamination was spread in the area between the HCW and the environment as well as on the cover of the rubbish bin when gloves were removed following a personal or causal method, and following the CDC glove removal procedure significantly decreased contamination of the environment and HCWs. Our findings underscore the importance of following the appropriate procedure for removing gloves and maintaining the proper distance between the HCW and the rubbish bin when discarding used gloves, as well as the need for proper training and supervision of minor staff in infection control measures.

Of course, caution is recommended when interpreting these data, given the limitations of this study. The unequal ratio of male and female subjects due to the female dominance of the nursing profession made it difficult to compare results, even though no sex-based differences were evident. The random sampling for future studies should recruit HCWs from a larger target population, such as different hospitals or clinics in Hong Kong. Despite these limitations, this study provides a valuable first step in examining how contaminants spread during glove removal and underscore the importance of following the CDC's glove removal procedure. Future studies should focus on examining the full PPE system and systematically recording the need for informed recommendations from the CDC regarding the removal of the full PPE system.

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