

Risk of self-contamination because of improper doffing of personal protective equipment: A randomised cross-over study

Address for correspondence:

Dr. Nishant Sahay,
House No. 110, Type 5 Block
2, AIIMS Residential Complex,
Khagaul, Patna, Bihar, India.
E-mail: nishantsahay@gmail.
com

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Nishant Sahay, Shagufta Naaz, Prabhat K Singh, Rajesh Kumar, Alok Ranjan¹, Vivekanand

Departments of Anaesthesiology and ¹Community and Family Medicine, AIIMS Patna, Bihar, India

ABSTRACT

Background and Aims: Many health care staff have been pressed into coronavirus disease-19 patient care with little experience of working in bio-hazard zones because of the overwhelming requirements of manpower. They wear personal protective equipment (PPE) and follow all rules for their safety. However, despite precautions, during doffing, they carry a risk of self-contamination. This randomised cross-over study assessed the risk of self-contamination because of improper doffing of PPEs. **Methods:** A colourless lotion that glows with a bright-green fluorescent hue under ultraviolet light was applied to simulate germ contamination in various health care workers (HCWs) who volunteered for the study. The primary objective of this study was to know the percentage of HCWs getting self-contaminated. The secondary objectives were to assess which portions of the body get maximally contaminated and infestation of germs on which portions of the PPE carry more risk of self-contaminating after doffing. **Results:** A total of 152 doffings by 76 participants were analysed, and the volunteers self-contaminated in 43 doffings (28.28%). In 18 of these 43 doffings, self-contamination was noted at more than one location. The most commonly contaminated areas were the arms (33%), clothes on the abdomen (24%), and areas in the lower limb (23%). Germ infestation on the upper parts of a PPE is 2.39 times more likely to cause self-contamination after improper doffing. **Conclusion:** Faulty doffing resulted in self-contamination in 28.28% of all doffings. Risk is 2.39 times more when germs are nested in the upper body portions of the PPE suit.

Key words: Clothing, health personnel, personal protective equipment, volunteers, workforce

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INTRODUCTION

The paranoia surrounding coronavirus infectivity is unprecedented. Health care workers have been known to suffer from significant mental distress because of the fear of either contracting the disease or transmitting it to a susceptible loved one. Researchers have studied the role of contamination fear among medical professionals as predictors of anxiety and safety behaviours in response to coronavirus disease-19 (COVID-19).^[1] Risk of self-contamination during doffing is a real threat and there have been protocols set for doffing sequences.^[2] The coronavirus pandemic is unique because of its sheer magnitude.^[3] Workers, not exposed to such specialised equipment and environment, have been forced to take up different responsibilities. Fear of the disease forces them to

take all due precautions and care. However, despite the care, many workers are likely to self-contaminate themselves, simply because of faulty doffing practices. In an interesting report, the authors have stated that no participant in their entire study group was observed to possess the correct knowledge on the steps of donning (0%) or doffing (0%) of personal protective

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equipment (PPE).^[4] Some other authors report that only 12.1% and 54% of the respondents had adequate knowledge of correct doffing practices.^[5,6]

The aim of this study was to assess the risk of contamination of health care workers by germs because of improper doffing practices. Our primary objective was to note what percentage of health care workers had contamination on their person by a lotion simulating germs after doffing. Our secondary objectives included assessment of which portion of the health care worker gets maximally contaminated after doffing, and also to assess infestation of which portion of the PPE carries the maximum risk of contaminating a health care worker after doffing.

METHODS

The study was approved by the institutional ethics committee (vide approval number IEC/2020/585 dated 25/11/2020) and written informed consent was obtained from all subjects participating in the trial. The trial was registered prospectively vide CTRI/2020/12/029654 dated 9th December 2020. Health care workers, including doctors, nursing staff, and cleaning staff working in a tertiary COVID care centre, discharging duties in areas where wearing PPE is mandatory, were chosen. The PPE kits were all DuPont™ Tyvek® controlled environments garments made by DuPont with a proprietary flash-spinning process that creates continuous fibres of high-density polyethylene. These fibres are 0.5–10 µm in diameter, some of which may be a tenth of the width of human hair.^[7] The components of the PPE were gloves, gowns, shoe covers, head covers, masks, respirators, eye protection, face shields, and goggles.

The study was conducted between December 2020 and May 2021. All adult volunteers working in COVID care areas were explained about the protocol and a written informed consent was obtained before being enrolled into the study. Any worker with known skin disease, use of any skin lotion in the last 24 h, pregnant women, and patients with history of any respiratory illness and presence of recent upper respiratory tract infection were excluded. For the experiment, a non-toxic lotion called Glo Germ™ manufactured by Glo Germ Company, Utah, the United States of America was used. Glo Germ™ is commercially available in the form of a gel, lotion, liquid, and powder. It is invisible to the naked eye but glows under ultraviolet (UV) light [Figure 1]. All participants meeting the inclusion criteria were



Figure 1: Note the glow of self-contamination under ultraviolet light, on skin of the forearm

randomly assigned to either upper body (UB) group or lower body (LB) group. For participants who had been allotted the UB group, six predetermined areas of the PPE were smeared using about one teaspoon of the Glo Germ™ lotion at each location. Thus, about six teaspoons were used for each session per person. Following areas were smeared: the top of the hood, anterior aspect of both shoulders, middle of the back interscapular region, and anterior aspect of both forearms, using a plastic spatula.

For participants who had been allotted to the LB group, one teaspoon of the Glo Germ™ lotion was applied similarly at the predetermined six areas on the lower part of the PPE, namely, on the anterior aspect near anterior superior iliac spine area, bilaterally behind the thighs and bilaterally on anterior aspect of the lower shin just above the shoe cover. To ensure blinding, a moisturiser similar in appearance to the Glo Germ™ lotion but which remains invisible even under UV light was applied on upper body areas for volunteers in LB group and lower body areas for volunteers in UB group. A large poster detailing the proper doffing sequence was displayed at all the designated doffing areas for male and female doctors and other staff. The doffing area had a chair to aid in doffing. After doffing, all participants were scanned using an 18 Watt 100 light emitting diode UV torch with a 395-nm wavelength, for presence of any fluorescent residue that glows under UV light in a dark room. Location of contamination was noted, including the following areas: hair and head, face, anterior/posterior neck, left/right arms, hands or wrists, front and back of chest, abdominal area and lower back, and legs and clogs. Location and total number of such contaminations were counted. Maximum dimension of contamination

was measured in centimetres. At a later date, as per their duty schedule, the group of participants was crossed over so that the participants of UG group now became the LG group and vice versa and the experiment was repeated.

For sample size calculation, it was assumed that when following training and all protocols strictly, approximately 1% participants may self-contaminate themselves. Some previous studies report self-contamination rates of about 18.9% despite care and after training.^[8] Assuming a correlation between paired observations at 5% and after applying continuity correction, the study would require a sample size of 67 pairs to achieve a power of 80% and a two-sided significance of 5% for detecting a difference of 0.14 between the two proportions. Anticipating a 15% drop-out rate, a total of 78 participants were recruited for this study.

All analyses were performed using Stata, version 10 (Stata Corp, Texas, the USA). Continuous variables were presented as mean \pm standard deviation. Categorical variables were presented as proportion. Student's *t*-test was used to test the difference of mean after checking for the equality of variance using F-test. Mann-Whitney test was applied to test the equality of distribution between the two groups. Chi-square test was used for comparing categorical variables. *P* value < 0.05 was considered as statistically significant.

RESULTS

Seventy-eight participants actively working in ward areas and intensive care units (ICUs) in a tertiary COVID care hospital volunteered and consented for the study. Two participants could not be crossed over for the study after the first doffing; hence, they were excluded from the analysis. The cross-over study design permitted assessments after 152 doffings by 76 volunteers, although a total of 154 doffings were studied.

Out of the 76 participants who were analysed, 48 (63.1%) were males and 28 (36.8%) were females [Table 1]. There was no significant difference of age between males and females ($P = 0.353$). Nearly, 64% of the participants were nursing staff, followed by 20% doctors and the rest were non-medical staff posted in the COVID-19 ward and ICU areas in the hospital. There was no significant difference in the

distribution of educational level of the participants by gender ($P = 0.111$).

Out of a total of 152 doffings observed, the doffing resulted in self-contamination at least 43 times. After 18 doffings, there was more than one area of contamination. There was no significant difference between males and females in case of contaminations.

Analysing the consolidated distribution of contamination by gender, we found no significant association of gender with contamination observed in UB ($P = 0.998$) or LB ($P = 1.00$) group [Table 2]. When the areas of self-contamination were assessed, the most common areas were observed to be on the upper limbs (arms and forearm) in 17 participants, followed by the abdomen in 15 participants and the lower limbs in 12 participants [Table 3]. However, we observed a significantly higher incidence of self-contamination when upper portions of a PPE were smeared with the gel compared to when lower parts of the PPE were smeared ($P < 0.001$). It shows that the risk of self-contamination by improper doffing is higher when upper portions of the PPE are contaminated.

Self-contamination was observed on more than one site of the body in 18 out of the 152 doffings. There was no significant association of gender with multiple self-contaminations in UB group ($P = 0.309$) or LB ($P = 0.977$) group [Table 4]. The incidence of self-contamination in more than one area was significantly higher when the gel was applied on the upper portions of the PPE ($P = 0.024$). Comparing the size of the biggest areas of contamination in both groups, we noted that in the UB group, median size of the largest area of contamination was 1.75 cm (inter quartile range – IQR: 0.5–3.5) compared to 1 cm (IQR: 0.5–2) in the LB group. This difference was not significant (Mann-Whitney $Z = 0.667$; $P = 0.505$). Even the size of secondary areas was comparable in both the groups (Mann-Whitney $Z = 0.372$; $P = 0.710$).

DISCUSSION

We noted self-contamination because of the improper doffing in a significantly high percentage of health care workers. Out of the 152 doffings studied, 43 doffings (28.28%) resulted in self-contamination that is high because all participants had been imparted formal training in the practice of doffing. Another figure of concern is that in 18 of these 43 doffings, self-contamination was noted at more than one

Table 1: Socio-demographic characteristics of the participants

Variables	Male (n=48)	Female (n=28)	Total (n=76)	P
Mean age (years)±(SD)	28.39±3.20	27.67±3.28	28.13±3.23	0.3533
Nursing staff				
Doctor	26	23	49	Chi-square=7.5071 P=0.111
Non-medical staff	11	4	15	
Post-graduates	3	0	3	
Graduates	4	1	5	
Matriculation	4	0	4	

SD: Standard deviation; n: Number

Table 2: Consolidated genderwise distribution of self-contamination observed on at least one site

Self-Contamination Present	Upper Body Group			Lower Body Group		
	Male	Female	Total	Male	Female	Total
Yes	20	12	32	07	04	11
No	28	16	44	41	24	65
Total	48	28	76	48	28	76
	Chi-square=0.01028, P=0.998			Chi-square=0.00126, P=1.00		

Table 3: Location wise distribution of self-contaminations

Areas of Contamination	Upper Body			Lower Body		
	Male	Female	Total	Male	Female	Total
Abdomen	5	5	10	4	1	5
Arms	12	4	16	0	1	1
Front chest	1	1	2	0	0	0
Rear chest	3	1	4	1	0	1
Leg	6	2	8	3	1	4
Neck	0	0	0	1	1	2
Lower back	1	1	2	1	1	2
Hand	2	1	3	0	0	0
Face	1	0	1	0	0	0
Total	31	15	46	10	5	15

Total of 61 contaminations were noted in 152 doffings. In 18 doffings, self-contamination was noted at more than one location. In 43 doffings, the self-contamination was limited to a single location

location. More than one area of contamination could point to significant errors in the process of doffing. The most common areas on the body for carrying these germs were the arms (33%), followed by clothes on the abdomen (24%), and closely followed by areas in the lower limb (23%). In a study on more than a thousand health care providers, the use of PPE was found to be appropriate in only 18.1% of users.^[5] Another study has surprisingly reported that none of the participants had satisfactory knowledge of donning or doffing practices.^[3] When the impact of doffing errors on contamination as evidenced by culture of multidrug-resistant organisms was assessed in a study, the authors found that 36% of health care workers were contaminated with these organisms after patient interactions.^[9] Our results also point to a significant risk of self-contamination despite regular training. In addition to regular training, a poster depicting the correct sequence of doffing is displayed in all the doffing areas in our hospital [Figure 2]. We have a clean and dirty chair in the designated areas to

aid doffing, although no doffing mates are present. The doffings are usually unmonitored and even during this study, we did not endeavour to study the mistakes made during doffing. One suggested measure to prevent errors could be the presence of a doffing mate. We noted that when upper portions of PPEs were smeared with the Glo Germ™ lotion, the risk of self-contamination was more than 2.39 times. Although we cannot comment on the exact reasons for this observation, one possibility could be that the upper suit areas are the first to be handled while doffing. Contamination on the gloves may spread germs. The arms were most commonly contaminated. The risk of multiple contaminations is also higher when germs are nested on the upper portions of the PPE.

The make and material of a PPE could affect rates of self-contamination. If there are PPEs made of cotton, the material would augment the absorption of droplet contaminants.^[9] This would reduce opportunities for such contaminants to spread to the environment. However, absorbent cottonoid fabric has been shown to increase undergarment contamination.^[10] Plastic aprons have been shown to result in maximal self-contamination on the hands and shoes. No plastic apron was used by our participants; however, it is a practice to use a plastic apron over a PPE at some places. Plastic has low water-absorbing properties.^[9] Aerosols containing these germs cannot be absorbed by plastic and are left on the surface of the plastic PPE. This increases the risk of self-contamination as well as the risk of environment contamination significantly.^[9] Another important concern with unwoven water-impermeable PPE suits is that, during doffing, if any extra force is applied in pulling off

Table 4: Doffing resulting in more than one areas of contamination

Contamination on More Than One Site	Upper Body			Lower Body		
	Male	Female	Total	Male	Female	Total
Yes	11	3	14	3	1	4
No	37	25	62	45	27	72
Total	48	28	76	48	28	76
	Chi-square=1.034, P=0.309			Chi-square=0.0008, P=0.977		

Chi-square=5.104, P=0.024 (significant <0.05)

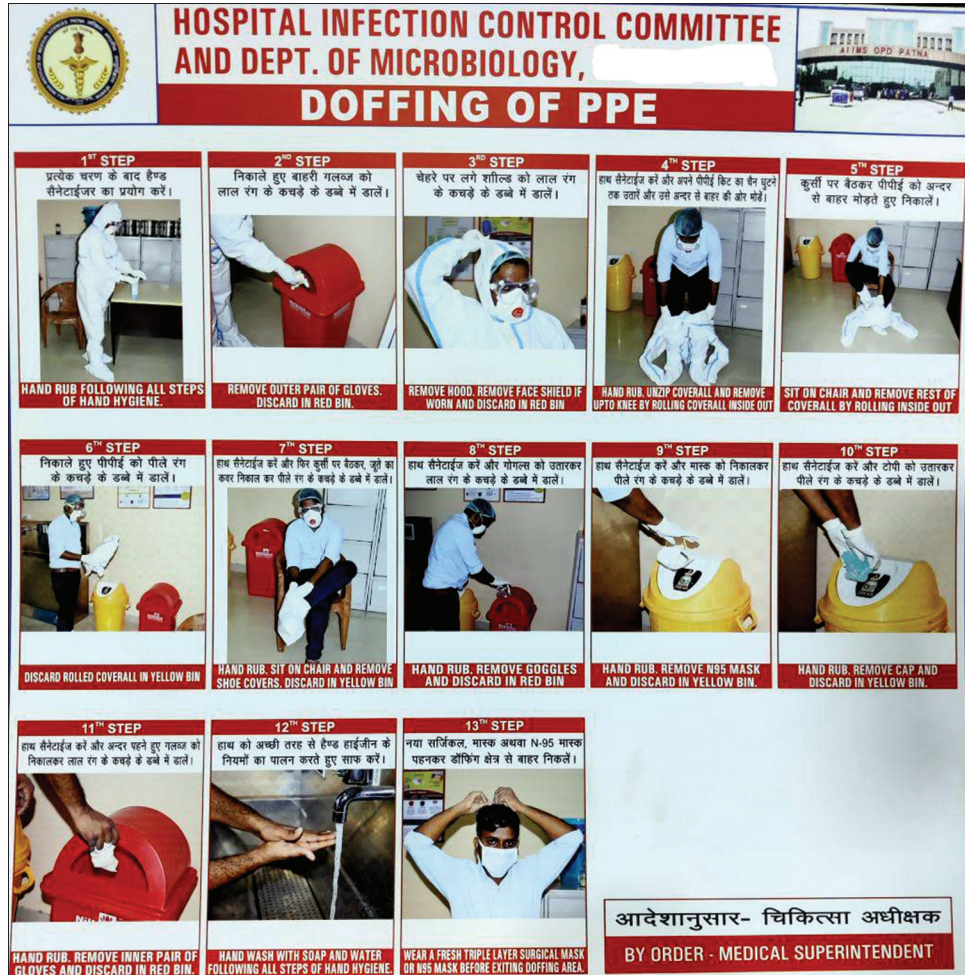


Figure 2: Sequence of doffing displayed in all the doffing areas

without unzipping or unfastening the ties, tearing off could spread the contaminants to the clean areas of a person doffing it. It could also send the contaminants splashing to the surrounding environment resulting in greater environmental contamination. In our study, we have used Tyvek® controlled environments garments manufactured by DuPont™ and made of continuous fibres of high-density polyethylene. These have low water permeability.

No difference in the rates of self-contamination based on gender was noted in our study. Both genders were equally likely to have multiple areas

of self-contamination, probably because there is no difference in the PPEs for males and females and the doffing sequence remains the same. The areas of contamination were bigger in the UB group compared to the LB group (1.5 cm versus 1.0 cm); however, this was not statistically significant. We also noted that level of education did not have any significant effect on the rates of self-contamination across gender. The cross-over design also allowed us to identify three participants who self-contaminated themselves both times, when they were assessed. This highlighted a possible basic flaw in their technique of doffing. One of these three was a doctor who also had multiple

areas of contamination during one doffing session. He was informed about the results and advised to follow the doffing sequence more carefully. Our method of assessment can, thus, be used to train and assess the correct method of doffing among staff members.

Despite the acute resource crunch, we believe that the presence of a doffing mate, if feasible, who could observe the doffings, and may or may not necessarily intervene during the process, could help at times of shift changes.^[11] Also, a post-doffing shower could help clean off these contaminants. Many staff wore the PPE over their regular clothes. A change to hospital scrubs and an above elbow scrub, post doffing, should be made mandatory where post-doffing showers are not feasible.

The strength of the study is that it was a prospective cross-over randomised trial pragmatically assessing doffing practices without intervention. The assessment involved not only trained doctors and nursing staff but also common non-technical staff in the exercise.

The limitations of the study are that this was a single-centre study with different protocols and infrastructure that may be different from other centres. The risk of self-contamination as assessed by this study would be lesser than the actual risk of self-contamination because only one-half of the PPE was smeared at one time, and in actual practice, such selective infestation is unlikely. Having said that it is also possible that all the smeared areas may not be infested in an individual at all the times either in the UB or LB. This may be fodder for further research; however, a rate of self-contamination of 28% is still high.

CONCLUSION

Faulty technique resulted in self-contamination in 28.28% of all doffings. This risk of self-contamination is 2.39 times more when germs are nested in the UB portions of the PPE suit. In 18 out of 43 faulty doffings, there was more than one area of contamination, which may reflect gross shortcomings in the method of doffing.

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Conflicts of interest

There are no conflicts of interest.

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