The Prevalence, Characteristics, and Prevention Status of Skin Injury Caused by Personal Protective Equipment Among Medical Staff in Fighting COVID-19: A Multicenter, Cross-Sectional Study

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Objective: To investigate the prevalence, characteristics, and preventive status of skin injuries caused by personal protective equipment (PPE) in medical staff.

Approach: A cross-sectional survey was conducted online for understanding skin injuries among medical staff fighting COVID-19 in February 8–22, 2020. Participants voluntarily answered and submitted the questionnaire with cell phone. The questionnaire items included demographic data, grade of PPE and daily wearing time, skin injury types, anatomical sites, and preventive measures. Univariable analyses and logistic regression analyses were used to explore the risk factors associated with skin injuries.

Results: A total of 4,308 respondents were collected from 161 hospitals and 4,306 respondents were valid. The overall prevalence of skin injuries was 42.8% (95% confidence interval [CI] 41.30–44.30) with three types of device-related pressure injuries, moist-associated skin damage, and skin tear. Co-skin injuries and multiple location injuries were 27.4% and 76.8%, respectively. The logistic regression analysis indicated that sweating (95% CI for odds ratio [OR] 87.52–163.11), daily wearing time (95% CI for OR 1.61–3.21), male (95% CI for OR 1.11–2.13), and grade 3 PPE (95% CI for OR 1.08–2.01) were associated with skin injuries. Only 17.7% of respondents took prevention and 45.0% of skin injuries were treated.

Innovation: This is the first cross-sectional survey to understand skin injuries in medical staff caused by PPE, which is expected to be a benchmark.

Conclusion: The skin injuries among medical staff are serious, with insufficient prevention and treatment. A comprehensive program should be taken in the future.

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Keywords: COVID-19, personal protective equipment, medical staff, occupational injury, skin injury, cross-sectional survey

INTRODUCTION

Since December 2019, COVID-19 broke out and rapidly spread from Wuhan, China. More than 80,000 persons infected and 3,000 over patients were killed by the disease. The National Health Commission of the People's Republic of China announced that it was the largest public health emergency[1,2] and continuously revised the guidelines on COVID-19 diagnosis and treatment, aiming to control the epidemic and reduce the mortality rate.[2] Early study indicated that the confirmed cases and virus carriers can be the infected source by person-to-person.[3,4] Facing the big challenge, more than 40,000 medical staff volunteered to help Wuhan, and tens of thousands of other medical staff joined to fight the COVID-19 around China. They worked daily for 8–12 h wearing personal protective equipment (PPE), including protective masks, goggles, face shield, and protective gowns.[5,6] Unfortunately, 80% of them reported that different skin injuries damaged their health and increased the risk of infection.

CLINICAL PROBLEM ADDRESSED

Literatures reported that device-related pressure injury (DRPI),[7–10] moisture-associated skin damage (MASD)[10–13] and skin tears (ST),[13,14] mostly occurred in patients, but no report of skin injuries on medical staff wearing PPE has been seen. How were the prevalence and characteristics of skin injuries among medical staff? What were the problems in prevention and treatment? This should be addressed urgently. Therefore, we conducted a cross-sectional multicenter survey online to understand the kinds and prevalence, and related factors of skin injuries, to analyze the problems in the prevention and treatment of skin injuries among medical staff during the COVID-19 pandemic, and then to provide a basis for developing strategies.

MATERIALS AND METHODS

Study design

A cross-sectional multicenter study was designed to understand skin injuries occurring in medical staff fighting COVID-19 in China.

Participants and sample size

The sample size was based on the results of more than 80% skin damage reported by the first batch of medical staff fighting COVID-19 in Wuhan; the allowable error was 1.5% with a 95% confidence interval (CI) and calculated in 2,732 respondents. Considering 10% of invalid questionnaires possibly, a total of 3,036 respondents would be needed. This study was approved by the Medical Ethics Committee of Jingling Hospital, Medical School of Nanjing University.

Participant inclusion criteria were as follows. (1) According to the guidelines of the government,[5,6] those medical staff who cared for the suspicious COVID-19 cases in emergency departments and screening clinics were deemed with moderate-risk exposure, and should wear surgical masks with goggles or protective face masks and protective gowns (called as grade 2 PPE); those medical staff who cared for the COVID-19 patients in the infectious department, intensive care units (ICUs), and isolation wards were deemed with high-risk exposure, and should wear N95/KN95 respirators with goggles or protective face masks,[15] protective gowns, latex gloves, and shoes (known as grade 3 PPE). (2) Age ≥18 years, regardless of gender. (3) Voluntary participants.

Exclusion criteria were as follows. Medical staff who did not wear PPE or who did not contact the suspicious or confirmed COVID-19 patients.

Data collection tool

We designed a survey questionnaire according to relevant guides, research literature,[7–10] and reviewed and revised three times by consulting statistics experts, nursing managers, wound care experts, and feedback from some medical staff in Wuhan. It contained general data (gender, age, the current position and occupation), information on the wearing of PPE (grade of PPE and daily wearing time, sweating), data of skin injuries (types, anatomical locations, severity or symptoms, and when they happened), whether protection was taken (Yes/No), and what preventive measures were adopted (multiple choice) and measures adopted after injury (multiple choice).

Data collection method

We disseminated the questionnaire to the frontline medical staff via the WeChat social platform from February 8 to 22, 2020. The nominated responsible person from 12 hospitals disseminated the questionnaire link to WeChat groups of medical teams who were working in Wuhan and infectious departments or isolation wards or ICUs in other hospitals around the country. Then the link was

constantly forwarded to more working groups by WeChat to recruit enough medical staff. Participants voluntarily used their cell phone to answer and submit the questionnaire response online within 2 weeks.

Research quality control

We provided space for comments and multichoice response to questions to answer quickly and accurately. The classification of DRPI depended on the staging system in the 2019 International Guide for Prevention and Treatment of Pressure Ulcer/Injury.[16] The 2017 Centers for Medicare & Medicaid Services (CMS) definition was used to identify MASD, "It is caused by sustained exposure to moisture which can be caused, for example, by incontinence, wound exudate, and perspiration." It is characterized by inflammation of the skin, and occurs with or without skin erosion and/or infection.[11] Meanwhile, the 2017 CMS definition was adopted to identify ST: "a result of shearing, friction, or trauma to the skin that causes a separation of the skin layers. They can be partial or full thickness."[11] The classification of ST depended on the International Skin Tear Advisory Panel classification system, including no skin loss (type 1), partial flap loss (type 2), or total flap loss (type 3) (Fig. 1).[17]

Statistical analysis

All the data were derived from "The Questionnaire Star" website, and the analysis database was established after two researchers checked. The mean (standard deviation) was used to describe participants' characteristics for continuous variables. Categorical variables were described as frequencies (percentages). Univariate analysis was first performed for identifying potential factors for the skin injuries. Pearson's chi-square tests or Fisher's exact tests were used for comparing categorical data as appropriate. Significant variables with $p < 0.05$ on univariate analysis were entered multivariate logistic analysis. Binary logistic regression with backward method was used for identifying independent predictors for skin injuries. All analyses were done with the statistical software package SPSS 22.0 for Windows (SPSS, Chicago, IL).

RESULTS

General characteristics of medical personnel

In total, 4,308 responded from 161 hospitals in 28 provinces or autonomous regions in the whole country, and of the 4,306 respondents analyzed, 516 (12.0%) were male, 3,790 (88.0%) were female, 505 (11.7%) were doctors, and 3,801 (88.3%) were nurses. Mean age was 32.5 ± 7.1 years, with 2,903 (67.4%) respondents <35 years and 1,403 (32.6%) respondents ≥35 years. Of them, 1,396 respondents (32.4%) and 2,910 respondents (67.6%) wore grade 3 and grade 2 PPE, respectively. The average daily wear time was 7.7 ± 2.9 h, with 14.3% (615 respondents) and 85.7% (3,691 respondents) daily wear time ≤4 and >4 h, respectively. There were 34.1% (1,467 respondents) with heavy sweating while wearing PPE.

Prevalence and characteristics of skin injuries in medical staff

This survey found three kinds of skin injuries in medical staff wearing PPE, namely DRPI, MASD, and ST. In total, 1,844 respondents had 4,735 skin injuries with 2.6 skin injuries per person. The overall prevalence was 42.8% (95% CI 41.30–44.30), and the prevalence of DRPI, MASD, and ST was 30.0% (95% CI 28.69–31.41), 10.8% (95% CI 9.91–11.82), and 2.0% (95% CI 1.62–2.40), respectively. Of them, 386 respondents (27.4%) had 2 or more types of injuries (coinjuries), and 1,080 respondents (76.8%) had 2 or more anatomical part injuries (multiple site injuries). Furthermore, 304 respondents (78.8%) reported coexistence between DRPI and MASD, 51 respondents (13.2%) with coexistence among DRPI, MASD, and ST, 27 respondents (7.0%) with coexistence between DRPI and ST, and 4 respondents (1.0%) with coexistence between MASD and ST. Of 1,293 respondents with DRPI, 1,049 respondents (81.1%) were stage 1, 236 respondents (18.3%) were stage 2, and 8 respondents

Figure 1. The classification of ST by the International Skin Tear Advisory Panel. ST, skin tears.

Table 1. *The distribution of skin injury types and anatomical sites in medical staff (sites= 4,735)*

	Nose Bridge		*Cheeks*		*Ear*		*Forehead*		*Others*[a]		*Total*	
Skin Injuries	n	%	n	%	n	%	n	%	n	%	n	%
DRPI (n=1,293)	986	30.6	929	28.8	824	25.5	448	13.9	40	1.2	3,227	68.2
MASD (n=465)	363	29.4	338	27.3	309	25.0	201	16.3	26	2.1	1,237	26.1
ST (n=86)	74	27.3	74	27.3	67	24.7	51	18.8	5	1.8	271	5.7
Total (n=1,844)	1,423	30.1	1,341	28.3	1,200	25.3	700	14.8	71	1.5	4,735	100.0

[a]Others include armpit, groin, and extremity.
DRPI, device-related pressure injury; MASD, moisture-associated skin damage; ST, skin tears.

(0.6%) had deep tissue injury. All of the 86 respondents had type 1 ST. The proportion and location of DRPI, MASD, and ST are shown in Table 1.

The prevalence of skin injuries was higher in male than in female (59.7% vs. 40.5%, $p<0.001$), in doctors than in nurses (51.9% vs. 41.6%, $p=0.001$), in ones wearing grade 3 PPE than in ones wearing grade 2 PPE (88.5% vs. 21.0%, $p<0.001$), in ones with daily wearing time >4 h than in ones with daily wearing time ≤4 h (47.3% vs. 18.7%, $p<0.001$), in ones older than 35 years than in ones younger than 35 years (46.3% vs. 41.2%, $p=0.034$), and in ones with heavy sweating than in ones without heavy sweating (91.3% vs. 17.8%, $p<0.001$). Characteristics and univariate analysis of skin injuries are shown in Table 2.

Multivariate analysis of skin injury in medical staff

Skin injuries were set as the dependent variable (0 = none, 1 = yes), and the single factors of $p<0.05$ (Table 2) were set as the independent variables: male = 1, female = 0; wearing grade 3 PPE = 1, grade 2 PPE = 0; doctors = 1, nurses = 0, heavy sweat = 1, without sweat = 0. Daily wearing time >4 h = 1 and ≤4 h = 0. A multivariate logistic regression analysis was performed with the backward method. The variable of occupation and age was removed from the final multivariate logistic model, and the heavy sweat, daily wearing time, gender, and grade of PPE were retained in the model, which associated with the occurrence of skin injuries. The omnibus tests of the model coefficients were $\chi^2=3{,}023.496$ (df = 4, $p<0.001$). The Nagelkerke R^2 of model summary was 0.703, which meant that 70.3% of the observed variation of dependent variable could be explained by independent variables. The results are shown in Table 3.

Preventive and treating status of skin injuries in medical staff

In total, 763 (17.7%) respondents used preventive dressings or oil agents to prevent skin injuries. Of the 1,844 respondents who suffered skin injuries, 1,014 (55.0%) respondents had no treatment and 830 (45.0%) respondents were treated by dressings, oil agents, or other methods. The details are shown in Table 4.

Table 2. *Characteristics and univariate analysis of skin injuries in medical staff (n= 4,306)*

Characteristics	n	*Prevalence of Skin Injuries,* n *(%)*	*95% CI for Prevalence*	p
Gender (male)				<0.001
Male	516	308 (59.7)	55.40–63.90	
Female	3,790	1,536 (40.5)	39.00–42.10	
Occupation				0.001
Doctors	505	262 (51.9)	47.50–56.30	
Nurses	3,801	1,582 (41.6)	40.10–43.20	
Heavy sweat				<0.001
Yes	1,467	1,340 (91.3)	89.90–92.80	
No	2,839	504 (17.8)	16.30–19.20	
Grade of PPE				<0.001
Grade 3	1,396	1,236 (88.5)	86.90–90.20	
Grade 2	2,900	608 (21.0)	19.50–22.40	
Daily wearing time (h)				<0.001
≤4	674	126 (18.7)	15.70–21.60	
>4	3,632	1,718 (47.3)	45.70–48.90	
Age (years old)				0.034
<35	2,903	1,195 (41.2)	39.40–43.00	
≥35	1,403	649 (46.3)	43.60–48.90	

CI, confidence interval; PPE, personal protective equipment.

Table 3. *Multivariate analysis of factors associated with skin injuries*

Factors	*OR*	*95% CI*	p
Heavy sweat (1)	119.48	87.52–163.11	<0.001
Gender (male)	1.54	1.11–2.13	0.008
Grade of PPE (1)	1.47	1.08–2.01	0.014
Daily wearing time (1)	2.27	1.61–3.21	<0.001
Constant	0.02		<0.001

OR, odds ratio.

DISCUSSION

Prevalence and characteristics of skin injuries in medical staff were different

The pandemic outbreak of COVID-19 raised a new issue of global concern since December 2019, skin injuries among medical staff wearing PPE that impaired their health and increased the probability of infection. More than 3,000 medical staff were infected in China and much more in other countries. Subsequently, the government released an urgent notice that further protected medical staff during COVID-19 control efforts.[18] Therefore, this study provided a basis for further protecting medical staff, and provided a reference for protecting skin when fighting COVID-19 in other countries. A higher prevalence of skin injuries among medical staff was found, mainly coexistence of DRPI, MASD, and ST with coinjuries and multiple anatomical sites (Tables 1 and 4). That is rare in previous studies in patients. ICU, orthopedic, and geriatric patients were the susceptible population of DRPI, MASD, and ST.[11–13] Different devices caused different skin injuries and prevalence,[7–10,12,13,19] and many differences were found between medical staff and patients. First, the prevalence of DRPI 30.0% (95% CI 28.69–31.41) in medical staff was higher than in patients using respiratory devices, tubes, and splints (3.1–27.9%).[8,10] Second, the prevalence of MASD 10.8% (95% CI 9.91–11.82) in medical staff was lower than in patients in ICU (20%),[20] but higher than in patients with chronic wounds (6.06%).[21] Third, the prevalence of ST 2.0% (95% CI 1.62–2.40) in medical staff was higher than 1.06% in patients in a multicenter study,[14] but significantly lower than 22% elderly patients in a systematic review.[22] Fourth, the susceptible parts of skin injuries in medical staff were on the nose bridge, cheeks, ears, and forehead (Table 1), and in patients, DRPI mainly located on ears and feet,[10,23] MASD occurred on skin fold, periwounds, or peristoma,[19–22,24,25] and ST occurred on extremities.[14,22] The reasons possibly were as follows. (1) Devices and wearing time in medical staff were different. According to Chinese regulations, medical staff wearing PPE should be replaced every 4 h. However, they actually had to work 8–12 h continuously due to the serious epidemic situation and inadequate medical resources. Of their long hours wearing PPE, the N95 respirators or surgical masks[15,25] and goggles would compress nose bridge and cheeks, a mask strap would compress the ears, and face shield and surgical cap would compress the forehead, which might be the main cause of skin injuries on multiple parts of the head and face. (2) Different activity possibly resulted in different skin injuries. Most of the patients were in bed, while medical staff moved rapidly to save more people's lives with long hours and high-intensity work, which was why 1,467 (34.1%) respondents reported heavy sweating and soaked skin. Moreover, the heavy and airtight PPE made it difficult to volatilize perspiration, which changed the skin microclimate and decreased skin tolerance.[12,13] All these factors would influence the development of skin injuries. (3) Sweating stimulated the skin and caused redness, pain, itching, or prickling, which might be the main cause of MASD. (4) Soaked skin combined with pressure increased friction coefficient between the PPE and skin, and when masks and goggles were removed quickly, ST was ready to happen. To sum up, these might be the reasons of coinjuries and multiple anatomical site injuries in medical staff (Fig. 2).

Table 4. *Prevention measures for skin injuries (n = 1,407)*

		Foam		*Hydrocolloid*		*Oil or Cream*		*Oil with Dressings*		*Personal*		*Untreated*	
Skin injuries	n	n	%	n	%	n	%	n	%	n	%	n	%
DRPI (a)	911	57	6.3	203	22.3	89	9.8	68	7.5	75	8.2	419	46.0
MASD (b)	106	5	4.7	10	9.4	38	35.9	4	3.8	10	9.4	39	36.8
ST (c)	4	0	0.0	1	25.0	2	50.0	0	0.0	0	0.0	1	25.0
a+b	304	17	5.6	60	19.7	47	15.5	49	16.1	30	9.9	101	33.2
a+c	27	0	0.0	6	22.2	6	22.2	5	18.5	2	7.4	8	29.6
b+c	4	0	0.0	0	0.0	1	25.0	1	25.0	2	50.0	0	0.0
a+b+c	51	3	5.9	12	23.5	4	7.8	22	43.1	1	2.0	9	17.7
Total	1,407	82	5.8	292	20.8	187	13.3	149	10.6	120	8.5	577	41.0

Figure 2. **(A)** DRPI+MASD on forehead. **(B)** MASD+ST on hands. **(C)** DRPI+ST+MASD on face. **(D)** ST on forehead. **(E)** MASD on palm. **(F)** MASD+DRPI on neck. DRPI, device-related pressure injury; MASD, moisture-associated skin damage.

The related factors of skin injuries in medical staff were different

This study showed that the prevalence of skin injuries between doctors and nurses, male and female, grade 3 and grade 2 PPE, daily wearing time ≤4 and >4 h, with and without heavy sweating, age <35 and ≥35 years old was different (all $p < 0.05$–0.001) (Table 2). The logistic regression analysis showed that (Table 3) the grade of PPE, daily wearing time, heavy sweating, and gender (male) increased risk of skin injuries. First, heavy sweating significantly increased risk of skin injuries (odds ratio [OR] 119.48, 95% CI 87.52–163.11, $p < 0.001$), and it could be related to increasing perspiration when medical staff were wearing PPE. It means that controlling the sweat and moisture on the skin is very important. Second, daily wearing time (OR 2.27, 95% CI 1.61–3.21, $p < 0.001$) can be predicted that the longer wearing time, the greater risk of skin injuries. This is also the reason why PPE should be replaced every 4 h, as given in the national guidelines, which also proves its necessity again. Third, male (OR 1.54, 95% CI 1.11–2.13, $p = 0.008$) increased risk that may be related to sweating more easily than female, and most Chinese men do not pay much attention to daily skin care. It means that males need more skin protection. Fourth, grade 3 PPE (OR 1.47, 95% CI 1.08–2.01, $p = 0.014$) increased risk that may be related to sweating more and compression. Thus, skin injuries caused by PPE are a comprehensive effect. It means that comprehensive preventive measures are needed.

Insufficient prevention and treatment in medical staff were a big problem

The study showed that only 17.7% of respondents used prophylactic dressings and lotions to protect the skin, and of them, 40% of respondents with sweating and wearing grade 3 PPE took preventive measures. Only 45.0% of respondents with injuries adopted hydrocolloid dressing, oil, or cream to treat (Table 4). It meant that prevention and treatment were insufficient. The reasons may be related to the following factors. First, medical staff and managers ignored skin protection at early stage. Second, medical staff in the frontline received no training how to prevent and treat skin injuries, and little was known how to use dressings. Some worried that if they used dressings to protect their nose bridge and cheeks, the mask and goggles would not close enough and possibly bring higher

infected risk. Finally, relevant preventive resources in response to public health emergencies were inadequate, and so, medical staff used what was available. This study suggests that it is necessary to make adequate preparations for public health emergencies. First of all, managers should pay attention to skin protection and seek a rational allocation of medical resources. Then, it is more important to train medical staff about knowledge of skin protection by WeChat, booklets, and so on. Furthermore, the protective products should be selected according to the guidelines, such as prophylactic dressings and fatty acid cream.[15,25,26] The material and shape of prophylactic dressings should be improved in the future, such as to develop various prophylactic dressings suitable for the head and face to effectively keep the moisture balance and protect skin, which are beneficial to deal with skin injuries of medical staff in public health emergencies.

KEY FINDINGS

- This study demonstrated that the prevalence of skin injuries among medical staff caused by PPE fighting COVID-19 was higher. It was characterized by coinjuries and multiple site injuries, affecting their health and occupational safety, even becoming potential risk factors for them with COVID-19.
- We found that four related factors (heavy sweating, longer daily wearing time, male, and wearing grade 3 PPE) might increase the risk of skin injuries.
- The deficiency of prevention and treatment cannot be ignored.
- Comprehensive preventive measures such as improving PPE, shortening wear time, and taking protective measures should be taken.

Limitations

Because of the emergency situation, there are some limitations to this study, such as it was difficult to observe the adverse outcome of skin injuries among medical staff and impossible to compare the results of prevention and treatment measures. These might leave us opportunities for further study.

INNOVATION

In response to the problems in the COVID-19 pandemic, we developed a questionnaire of the first-time surveyed skin injuries among medical staff wearing PPE. We found a higher prevalence of skin injuries characterized by coinjuries and multipart injuries, four related factors, and insufficient prevention and treatment status. This will provide a basis for protecting medical staff and improving PPE around the world.

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AUTHOR DISCLOSURE AND GHOSTWRITING

The authors declare that they have no conflicts of interest in this work. No ghost writer was used for the preparation of this article.

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Abbreviations and Acronyms

CI = confidence interval
CMS = Centers for Medicare & Medicaid Services
COVID-19 = corona virus disease 2019
DRPI = device-related pressure injury
ICU = intensive care unit
MASD = moisture-associated skin damage
OR = odds ratio
PPE = personal protective equipment
ST = skin tears