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Stockpile of personal protective equipment in hospital settings: Preparedness for influenza pandemics

Mayuko Hashikura, BS, and Junko Kizu, PhD
Tokyo, Japan

Background: Personal protective equipment (PPE) is known to be a crucial means of preventing influenza pandemics; however, the amount of PPE that should be stored in hospital settings has been unclear.
Objectives: The purpose of this paper is to propose a PPE calculation system to help hospitals to decide their PPE stockpile.
Methods: We searched influenza guidelines from a number of countries and research papers on protective devices and infectious diseases. The PPE calculation system included factors such as the influenza pandemic period, risk classification by health care workers (HCW) type, and the type and number of PPE for a HCW per day.
Results: We concluded that 4 sets of PPE (N95 respirators, double gloves, gowns, and goggles) per day should be prepared for HCWs in a high-risk group. Similarly, 2 sets of appropriate PPE, depending on the risk level, are required for medium- and low-risk groups. In addition, 2 surgical masks are required for every worker and inpatient and 1 for each outpatient. The PPE stockpile should be prepared to cover at least an 8-week pandemic.
Conclusion: Purchasing a PPE stockpile requires a sizable budget. The PPE calculation system in this paper will hopefully support hospitals in deciding their PPE stockpile.
Key Words: Personal protective equipment; respirators; masks; infection control; disease outbreak.

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Human life has often been threatened by influenza pandemics, such as the ''Spanish flu'' in 1918, ''Asian flu'' in 1957, and ''Hong Kong flu'' in 1968. Above all, the Spanish flu, which suddenly broke out in Western Europe during World War I, caused the worst damage: 40 million deaths and 600 million infected people all over the world and 380 thousand deaths and 23 million infected people in Japan.[1]

No major influenza pandemic has occurred since the beginning of the 21st Century; however, a pandemic might be imminent because it is known that influenza pandemics usually repeat within 10 to 40 years, and 40 years have already passed since the last pandemic: ''Hong Kong flu.'' In addition, development of transportation such as commercial flights in recent years makes it easy for infections to spread over seas. Severe acute respiratory syndrome (SARS) in 2003 was a good example of this.

During the SARS period, another key factor occurred: many health care workers (HCWs) who cared for SARS patients in hospital settings became infected. For instance, the rate of infected HCWs of all patients was 19% in China, 22% in Hong Kong, 20% in Taiwan, 43% in Canada, and 41% in Singapore, respectively.[2] On the other hand, there were rare cases, such as a hospital in Vietnam, which succeeded in treating patients without infecting HCWs, even though Vietnam's national rate of infected HCWs was extremely high (58%).[3] According to a study of this hospital, one of the factors that contributed to protecting HCWs from secondary infection was the use of personal protective equipment (PPE), such as N95 respirators, surgical masks, and gloves.

Given the lessons from SARS, PPE is considered essential as an infection control measure. It should also be noted that a large number of PPE will be required in the short-term because it is estimated that the rate of infected people would be 25% of the total population during an influenza pandemic.[4] The key question is how many PPE each hospital setting actually needs to purchase. The purpose of this paper is to establish a calculation system to decide the appropriate PPE stockpile in each hospital setting based on factors such as the influenza pandemic period, risk classification by the HCW type, and the type and

From the Department of Practical Pharmacy, Keio University Faculty of Pharmacy, Tokyo, Japan.

Address correspondence to Mayuko Hashikura, Department of Practical Pharmacy, Keio University Faculty of Pharmacy, 1-5-30 Shibakoen, Minato-ku, Tokyo 105-8512, Japan. E-mail: mayuko1201@hotmail.com.

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Table 1. Epidemical characteristic of SARS

	Number of infected patients	Number of deaths	First patient reported	Last patient reported	SARS-free declaration	Length (days)
China	5327	349	11/16/2002	6/3/2003	6/24/2003	224
Hong Kong	1755	299	2/15/2003	5/31/2003	6/23/2003	131
Taiwan	346	37	3/25/2003	6/15/2003	7/5/2003	103
Canada	251	43	2/23/2003	6/12/2003	7/2/2003	130
Singapore	238	33	2/25/2003	5/5/2003	5/30/2003	95

Table 2. Predicted lengths of influenza pandemics

Country	Pandemic period (wk)
Canada[7]	6-8
France[8]	8-12
Greece[9]	6-8
The Netherlands[10]	3 mo (90 days)
New Zealand[11]	8
Norway[12]	6 mo
Republic of Korea[13]	8
South Africa[14]	8-12
Sweden[15]	6-8
United States[16]	6-8

number of PPE required for HCWs per day. In addition, we investigated the average number for each HCW in hospital settings in Japan classified by the location and scale of hospitals so that PPE can be calculated from only the location and scale of hospitals. Finally, as an example, the stockpile of PPE needed for a sample hospital with 300 beds in Tokyo is shown using this system.

METHODS

Data search

A MEDLINE search was performed through PubMed for January 1950 to October 2008, using the search terms ''Protective Devices [MeSH Terms]'' and ''Disease Outbreak [MeSH Terms].'' Another MEDLINE search was performed using ''Severe Acute Respiratory Syndrome [MeSH Terms]'' and ''Epidemiologic Measurements [MeSH Terms].'' In addition, we searched reports and guidelines published by various organizations, such as the Ministry of Health, Labor and Welfare of Japan, the World Health Organization (WHO), the Centers for Disease Control and Prevention (CDC), and the US Department of Labor.

Data extraction

Based on the above data, we extracted various factors, such as the influenza pandemic period, the risk classification by the HCW type, and the type and number of PPE required for HCWs per day to calculate the stockpile of PPE in hospital settings.

PPE calculation system

We first obtained the average number of HCWs in hospital settings from the database of the Ministry of Health, Labor, and Welfare of Japan. We then developed a PPE calculation system, which can calculate the number of PPE from only the location and scale of the hospital. In this system, the stockpile of PPE is calculated by multiplying (1) the average number of HCWs determined automatically by the location and scale of the hospital, (2) the number of PPE sets required for HCWs per day, and (3) the length of the pandemic period.

As an example, the stockpile of PPE required for a sample hospital with 300 beds in Tokyo is shown using this PPE calculation system. The expenditure for PPE was calculated by multiplying the total stockpile of PPE by the average cost of PPE.

RESULTS

Data search

According to the search results by MEDLINE, there were 121 papers for ''Protective Devices [MeSH Terms]'' and ''Disease Outbreak [MeSH Terms]'' and 267 papers for ''Severe Acute Respiratory Syndrome [MeSH Terms]'' and ''Epidemiologic Measurements [MeSH Terms].'' In addition, we obtained influenza guidelines from 30 nations and SARS reports.

Influenza pandemic period

Based on the data obtained during the SARS epidemic in 2003, we calculated the pandemic period, assuming that it started from the day that the first patient was detected to the last day when a SARS-free declaration was issued by the country. As a result, the average duration was 122 days. The average was taken from the countries shown in Table 1, which included more than 100 patients. China was excluded because of the unhelpful actions of the government, such as concealment at the beginning of the SARS pandemic.

Table 3. Risk classification of HCWs

Risk	HCWs
High	• Doctors and nurses performing high-risk procedures (intubation, suctioning before intubation, manipulating the oxygen mask, and others[17])
	• Radiologists performing high-risk procedures (chest x-ray examinations of infected patients, and others[18])
Medium	• Doctors and nurses who perform medium-risk procedures (caring for infected patients in a stable condition, and others)
	• Medical clerks[19] (who have close contact with suspected or infected patients)
	• Cleaners who work in emergency departments or the intensive care units with high-risk patients[19]
Low	• Doctors and nurses who do not have contact with infected patients
	• Cleaners who work in SARS wards with infected patients in a stable condition

Table 4. Type of PPE appropriate for each risk classification

Risk	Personal protective equipment
High	N95 mask (with exhalation valve) Gown Goggle Gloves (double)
Medium	N95 mask Gown Goggle Gloves (double)
Low	Surgical mask Apron Gloves

However, the pandemic periods in each region may be shorter than 122 days, which is the national average. According to the US Department of Labor,[5] the pandemic period in each region is considered to be 12 weeks at maximum. In addition, the majority of guidelines of the countries that are introduced on WHO Web site[6] assume that the pandemic lasts 6 to 8 weeks (Table 2). The Ministry of Health, Labor, and Welfare of Japan also supposes that a pandemic will last 8 weeks[4]; therefore, a stockpile of PPE should be prepared to cover at least 8 weeks, although influenza pandemics could last longer with 2 or more waves.

Risk Classification of HCWs

The type of appropriate PPE for each HCW differs depending on the risk level. In this research, HCWs are classified into 3 groups: high risk, medium risk, and low risk (Table 3).

Table 5. Type and number of PPE required for HCWs per day

Type of HCW	Physicians (emergency department)	Other physicians		Nurses (emergency department)	Other nurses		Radiologists	Medical technologists	Pharmacists	Medical clerks	Others	Outpatients	Inpatients
Risk	High	Medium	Low	High	Medium	Low	High	-	-	Medium	-	-	-
Possible number of infected patients to treat/1 HCW	10	20	0	5	10	0	-	-	-	-	-	-	-
N95 masks	4			4			4						
(with exhalation valve)													
N95 masks		2			2								
Surgical masks	2	2	2	2	2	2	2	2	2	2	2	1	2
Goggles	4	2		4	2		4			2			
Gowns	4	2		4	2		4			2			
Aprons			2			2							
Gloves	20	40	2	10	20	2	8			2			

NOTE. Others includes medical office managers, care managers, cooks, and housekeepers.

Table 6. Stockpile of PPE required for a sample hospital of 300 beds during an influenza pandemic

Type of HCW	Physicians (emergency department)	Other physicians		Nurses (emergency department)	Other nurses		Radio-logists	Medical technologists	Pharmacists	Medical clerks	Others	Out-patients	In-patients				
Risk	High	Medium	Low	High	Medium	Low	High	-	-	Medium	-	-	-	Total	PPE cost (Yen)	Total cost (Yen)	Total cost (US $)
Number of HCWs	6	16	63	21	63	250	20	30	18	17	77	600	300				
N95 mask (with exhalation valve)	1,344			4,704			4,480							10,528	300	¥3,158,400	$31,584
N95 mask		1,792			7,056									8,848	210	¥1,858,080	$18,580.80
Surgical mask	672	1,792	7,056	2,352	7,056	28,000	2,240	3,360	2,016	1,904	8,624	33,600	33,600	132,272	30	¥3,968,160	$39,681.60
Goggle	1,344	1,792		4,704	7,056		4,480			1,904				21,280	900	¥19,152,000	$191,520
Gown	1,344	1,792		4,704	7,056		4,480			1,904				21,280	1000	¥21,280,000	$212,800
Apron			7,056			28,000								35,056	55	¥1,928,080	$19,280.80
Gloves	6,720	35,840	7,056	11,760	70,560	28,000	8,960			3,808				172,704	25	¥4,317,600	$43,176
																¥55,662,320	$556,623.20

NOTE. Others include medical office managers, care managers, cooks, and housekeepers.

Type and number of PPE required for each HCW per day

The type of PPE needed for each risk group is shown in Table 4. According to the US Department of Labor,[5] the number of PPE required for HCWs in a high-risk group is 4 sets per day. It is also considered that 2 sets of PPE are required for HCWs in medium- and low-risk groups because HCWs work around 12 hours a day and are required to change PPE every 6 hours during pandemics.[20]

The number of gloves depends on how many patients HCWs can treat because gloves should be changed for each patient. We suppose that 20 pairs of gloves/doctor (high risk)/day will be required because 1 SARS report showed that 1 doctor can treat 5 to 10 patients per day from the view of infection control.[21]

Furthermore, the use of masks by patients is also important to block virus transmission. The US Department of Labor indicates that 1 surgical mask per day is necessary for outpatients and 2 for inpatients.[5] All medical and nonmedical workers in the hospital, such as doctors, nurses, medical technologists, pharmacists, caregivers who provide critical care or spiritual care, respiratory therapists, reprocessors of reusable medical devices, and cafeteria workers, in addition to the family members and visitors, also require at least 2 surgical masks per day. The type and number of PPE required for each HCW per day are summarized in Table 5.

PPE calculation system

We developed a PPE calculation system based on the following factors: influenza pandemic period of 8 weeks, risk classification by the HCW type, and type and number of PPE required for HCW per day. This system made it possible to demonstrate (1) the average number for each HCW, (2) the required PPE stockpile, and (3) associated expenses from only the location and scale of each hospital. The allocation of doctors and nurses to each risk group is illustrated in Table 3. In this study, we allocated 1/16 of all doctors and nurses to the high-risk group, 3/16 to the medium-risk group, and remaining 3/4 to the low-risk group.

Finally, to give an example, we show the stockpile of PPE required for a sample hospital with 300 beds in Tokyo (Table 6). According to this system, the total number of PPE is 10,528 N95 respirators (with exhalation valve), 8848 N95 respirators, 122,192 surgical masks, 21,280 goggles and gowns, 34,832 aprons, and 172,480 pairs of gloves. The total expense for this hospital came to 55,342,000 yen (US $553, 420.00; $1=100 yen).

CONCLUSION

In recent years, the government of Japan has appropriated an enormous budget for preventive measures against influenza pandemics, but the major part of this budget is used to stockpile Tamiflu and Relenza and to develop a vaccine.[22] Considering that $1 million worth of PPE was required in the first week alone at the beginning of the SARS outbreak in Toronto,[23] PPE is as important as infection control measures. It also should be noted that stockpiling a sufficient number of PPE could be a large financial burden on each hospital; however, this must occur before pandemics break out, which will result in a massive shortage of PPE.

Stockpiling PPE at each hospital is a matter of great urgency. The PPE calculation system in this paper will hopefully help to estimate the stockpile of PPE for each hospital. After all, appropriate use of PPE is an essential factor to prevent the transmission of virus. Therefore, the education to HCW should be properly conducted in addition to stockpiling PPE before the pandemic occurs.

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