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Health care workers' views about respirator use and features that should be included in the next generation of respirators

Aliya S. Baig, MPH, MSN, Caprice Knapp, PhD, Aaron E. Eagan, RN, and Lewis J. Radonovich Jr, MD
Gainesville, Florida

Background: Numerous studies have demonstrated that health care workers are, in general, poorly compliant with respiratory protection guidelines, especially when a N95 respirator is recommended. The purpose of this study was to assess health care workers' views about respirator use and the features they prefer to be included in the next generation of respirators.
Methods: A 63-item survey was distributed to health care workers in 27 units of 2 tertiary care medical centers.
Results: From a total of 559 surveys distributed at both hospitals, 159 responses were returned (response rate, 28%). Survey results indicated that health care workers seek respirators that are more comfortable, interfere less with breathing, diminish heat buildup, are disposable, and permit the user to have facial hair. Multivariate analyses suggest that emergency department staff had 12.3 greater odds of wanting a new respirator ($P = .031$) as compared with their referent group. Males were more likely to indicate that the N95 respirator was comfortable to wear versus females ($P = .003$).
Conclusion: To increase substantially the acceptance of respiratory protective equipment and improve compliance rates, respirators should be modified to meet the specific needs of health care workers.
Key Words: Respirator; N95; occupational health; infection control; influenza; pandemic.

Published by the Association for Professionals in Infection Control and Epidemiology, Inc.
(Am J Infect Control 2010;38:18-25.)

Occupational risks assumed by many health care workers (HCWs) include exposure to a variety of airborne respiratory infectious diseases, such as tuberculosis and measles, and novel or emerging diseases such as severe acute respiratory syndrome (SARS) and novel H1N1 influenza A. Respiratory protective equipment is recommended as one method to diminish the risk of exposure.[1-4] However, numerous studies have demonstrated that HCWs are, in general, poorly compliant with respiratory protection guidelines, especially when a N95 respirator is recommended.[5-11] The designs and features of respirators may play an important role in compliance, but little more than anecdotal evidence exists to illuminate the details of this concept. Whereas many studies have probed the physiology of respirators,[12-20] few have explored features of respirators that influence compliance. Furthermore, managements' attitudes and organizations' safety culture may also play an important role in HCWs' compliance with wearing respiratory protective equipment.[6,21,22] Recently, the Institute of Medicine (IOM) recommended that the respirator manufacturing industry explore new respirator designs that meet the needs of HCWs.[23] This message has resonated within the health care community.[24] The purpose of this paper is to report the results of a survey exploring characteristics of respirators that may influence HCW compliance. These results may be important considerations when designing the next generation of respirators.

Over the last 2 decades, respiratory protective equipment has become commonplace in health care. In 1994, the Centers for Disease Control and Prevention (CDC) recommended a hierarchy of infection control measures to prevent the health care-associated

From the National Center for Occupational Health and Infection Control, Office of Public Health and Environmental Hazards, Veterans Health Administration, US Department of Veterans Affairs, Gainesville, FL.

Address correspondence to Aliya S. Baig, MPH, MSN, associate for Respirator Projects, National Center for Occupational Health and Infection Control, Office of Public Health and Environmental Hazards, Veterans Health Administration, US Department of Veterans Affairs, 1601 SW Archer Road (151B), Gainesville, FL 32608. E-mail: Aliya.Baig@va.gov.

Disclaimer: The views presented in this manuscript do not necessarily reflect the views or opinions of the Department of Veterans Affairs, the Office of Public Health and Environmental Hazards, the National Center for Occupational Health and Infection Control, the Veterans Health Administration, the National Institute for Occupational Safety and Health, the University of Florida, North Florida/South Georgia Veterans Health System, or any of the authors' other employers or affiliations.

Conflicts of interest: None to report.

0196-6553/$36.00

Published by the Association for Professionals in Infection Control and Epidemiology, Inc.

doi:10.1016/j.ajic.2009.09.005

transmission of *Mycobacterium tuberculosis* (TB) including administrative controls, engineering controls, and personal respiratory protective equipment.[4,25] As part of the final step in the hierarchy, the CDC recommended that HCWs use N95 respirators. This recommendation was based on case reports, theoretical and empirical data, laboratory simulation, and mathematical modeling,[25] although no definitive clinical trials had been conducted that demonstrated the effectiveness of respirators against TB or other airborne microorganisms in the health care workplace.

The Occupational Safety and Health Administration enforced CDC's guidelines through its respiratory protection standard (Code of Federal Regulations 29 Part 1910.134).[26,27] To meet the CDC's specific performance criteria for respirators, the National Institute for Occupational Safety and Health issued a new set of regulations, under Code of Federal Regulations 42 Part 84, that identified 3 classes of filters (N, R, and P) and 3 levels of filtration efficiency (95%, 99%, and 99.97%).[27] Based on the CDC's criteria for respirators, the Occupational Safety and Health Administration concluded the N95 respirator (where N95 means the respirator is not [N] resistant to oil and is capable of filtering at least 95% of particulates with a median aerodynamic diameter of 0.3 μm [the most penetrating particle size]) to be the ''minimally acceptable level of respiratory protection for TB.[28,29]

N95 respirators are among the most commonly used type of respirators in U.S. healthcare[30] and they differ significantly from surgical masks in that respirators are designed to reduce the wearers' risk of inhaling hazardous airborne particles, whereas surgical masks are typically worn to protect others from the wearers' exhaled secretions or coughs.[23] There are a limited number of studies in today's scientific literature examining the effectiveness of N95 respirators compared to surgical masks. Case control studies during the 2003 SARS crisis suggested that N95 respirators may be somewhat more protective than surgical masks against the SARS coronavirus.[31-35] More recently, a direct comparison of N95s to surgical masks found that surgical masks were not inferior to N95 respirators at protecting HCWs against influenza.[36] Unfortunately, this trial was terminated prematurely, limiting its power to detect differences in effectiveness, because of regulations pertaining to the 2009 H1N1 influenza pandemic. Surely, additional comparative effectiveness studies will follow in an effort to definitively determine the relative effectiveness of different respiratory protective devices.

The N95 is one type of air-purifying, filtering facepiece respirator that requires the wearer to draw air through the filter during inhalation. Another type of respirator is the powered air-purifying respirator, which supplies high-efficiency filtered air to the wearer. A powered air-purifying respirator has a loose hood or tight-fitting facepiece attached to a battery-operated fan that blows filtered air to the wearer, requiring less breathing resistance than the filtering facepiece. However, the powered air-purifying respirator is an expensive alternative to the N95, can interfere with occupational activities, and requires a battery source.[25]

Ideally, respirators used in the health care workplace should permit HCWs to perform their duties without interference. However, many studies of N95 respirators in the US marketplace have shown them to be associated with overall discomfort[23,30,37-39]; diminished visual,[17,38,40] vocal,[17,40] or auditory[17] acuity; excessive humidity[30] or heat[30,39,40]; headaches[23]; facial pressure[30]; skin irritation or itchiness[23,28,38]; excessive fatigue or exertion[23,30,38-40]; malodorousness[30,39]; anxiety or claustrophobia[23]; and other interferences with occupational duties.[25,39,41,42]

In 2007, the IOM published a report, ''Preparing for an Influenza Pandemic: Personal Protective Equipment for Healthcare Workers,'' that described the need to strengthen the design and testing of personal protective equipment.[23] The IOM identified the critical need to conduct research and develop better respiratory protective equipment for HCWs.[23] In an effort to build on the IOM recommendations, the Department of Veterans Affairs (VA), in collaboration with National Institute for Occupational Safety and Health, initiated Better Respiratory Equipment using Advanced Technologies for Healthcare Employees (Project B.R.E.A.T.H.E.), a federal interagency working group charged with developing a set of ideal performance characteristics for respirators in health care. The ultimate goal is to shepherd the development of new respiratory protective equipment for HCWs using a government/academic/private partnership model. With representatives from 9 federal departments and agencies, this multidisciplinary working group has a broad range of expertise, including pandemic and emergency preparedness, infectious disease medicine and epidemiology, infection control, respirator and personal protective equipment policy and regulation, occupational and environmental medicine, respirator and materials science, and biosecurity.[43] The survey reported in this manuscript was designed to help inform Project B.R.E.A.T.H.E. by elucidating some of the features preferred by HCWs for the next generation of respirators.

METHODS

Study design and participants

A survey instrument was designed and delivered to HCWs in 2 tertiary care medical centers in Gainesville, FL: the Malcom Randall VA Medical Center, a 200-bed

tertiary veterans hospital in the North Florida/South Georgia Veterans Health System; and Shands Hospital, a 618-bed academic teaching hospital at the University of Florida. Both hospitals were chosen for their close proximity to the research group. Permission to distribute the survey was granted by both institutions, including pertinent collective bargaining units. This study was approved by the University of Florida Institutional Review Board and the local VA subcommittees for clinical investigation and research and development.

Employees of the study sites were eligible to participate in the survey if they had worn a N95 respirator at least once, prior to completing the survey, while performing occupational duties. The eligible population included the following: nurses, physicians, respiratory therapists, housekeepers, patient care assistants, and other staff. Units (wards or departments) selected for survey distribution were identified through nursing council meetings and by directly approaching unit managers at both hospitals. Each unit manager requested the number of survey kits to be distributed for their unit. Each survey kit included a script for the survey distributor (eg, the unit manager) explaining to HCWs that their participation in the survey was completely voluntary, anonymous, confidential, and would have no impact, positive or negative, on their employment status; waiver of documentation of informed consent; a collection box; and multiple survey packets. Each survey packet included instructions for completing the survey, which also instructed participants not to take the survey if they had already completed one; a survey questionnaire; an envelope; and a pencil. Survey packets were distributed to HCWs by the unit manager during December 2008. A total of 559 surveys were distributed: 310 at the VA and 249 at the University hospital. Units that received survey kits included respiratory care, emergency care, ambulatory care, skilled nursing, medical/surgical, nursing education, medical intensive care, infectious disease, housekeeping, surgical intensive care, surgery (operating suites), and mental health. Collection boxes for completed .surveys were left on participating units for 3 weeks. No incentives were provided for completing the survey.

Survey instrument

An 8-page, 63-item survey with 5 open-ended questions was developed for the study. This survey instrument was based on information from published literature on factors that are known to influence adherence to universal precautions, and HCW compliance, with infection control procedures.[40,44-48] The theoretical model that guided survey development was the Predisposing, Reinforcing and Enabling Causes in Educational Diagnosis and Evaluation (PRECEDE) model adapted by DeJoy et al in 1986 to describe self-protective behavior at work.[46] One survey question was eliminated during data analysis because of a typographical error on the survey. Two of 5 survey sections that address work environment influences on respirator use and respirator training will receive minimal analysis in this manuscript and will be discussed elsewhere. This manuscript will focus on respirator features that are preferred by HCWs for the next generation of respiratory protection for HCWs. For the purpose of this paper, survey questions were divided into 3 sections: ''Section A: Summary Statistics'' described respondent characteristics, including gender, education, work setting, staff position, years of experience, time elapsed since last fit testing and N95 respirator use, and style of respirator worn. ''Section B: Comfort with N95 Respirators'' assessed HCW experiences when wearing N95 respirators. ''Section C: Desired Characteristics in a New Respirator'' examined HCW preferences for new respirator characteristics. All response categories for sections B and C were on a 5-point Likert scale.

Statistical analysis

Descriptive statistics were used to report respondents' demographic information and individual survey item responses. Multivariate analyses were also conducted to determine which individual HCW characteristics were associated with 2 dependent variables: (1) comfort with wearing a N95 respirator and (2) desire for a new respirator. Ordinary least squares regression was used to estimate the associations with several individual characteristics (eg, age, race, education, and others) and comfort when wearing a N95 respirator. To assess comfort, a domain score was created by assigning a value of 0 when the respondent ''always'' or ''most of the time'' agreed with the applicable survey items and a value of 1 otherwise.

A logistic regression was used to estimate the associations between the same individual characteristics and the desire for a new respirator. A value of 1 was assigned when respondents indicated that they ''agree'' or ''strongly agree'' with the survey question that asked whether there was a need to create a new N95 respirator for HCWs and a value of 0 otherwise. A priori level of statistical significance was set as $\leq .05$.

RESULTS

Response rate and demographics

One hundred fifty-nine (28%) of 559 surveys were returned, and the response rates were 30% and 26% from the VA and university hospitals, respectively. Ten of 159 surveys were eliminated from data analysis

Table 1. Summary statistics

N = 149	No. (%)
Sex	
Female	95 (63.8)
Male	54 (36.2)
Race	
White	106 (71.1)
Asian/Pacific Islander	15 (10.1)
African American	12 (8.1)
Hispanic	10 (6.7)
Age, yr	
18-29	18 (12.5)
30-39	34 (22.8)
40-49	45 (30.2)
50+	47 (31.5)
Marital status	
Single	33 (22.4)
Divorced, separated, widowed	27 (18.4)
Married or living with partner	87 (59.2)
Children	
Yes	102 (69.4)
No	45 (30.6)
Education	
High school/diploma	62 (41.9)
Bachelor's degree	58 (39.2)
Master's/MD/doctorate	25 (16.8)
Staff position	
Registered nurse	93 (62.4)
Respiratory therapist	14 (9.4)
Patient care assistant	12 (8.1)
Physician	7 (4.7)
Licensed vocational nurse	7 (4.7)
Housekeeper	6 (4.0)
Other	10 (6.6)
Work setting	
Medical/surgical	61 (41.5)
Intensive care	49 (33.3)
Emergency room	11 (7.5)
Operating room	6 (4.1)
Other	20 (13.6)
Length of time worked in hospital work area/unit, yr	
<1	29 (19.5)
1-5	69 (46.3)
6-10	29 (19.5)
11-15	12 (8.1)
16-20	6 (4.0)
≥21	4 (2.7)
Length of time worked in current specialty or profession, yr	
<1	16 (10.9)
1-5	41 (27.9)
6-10	18 (12.2)
11-15	32 (21.8)
16-20	12 (8.2)
≥21	28 (19.0)

because respondents had never worn a N95 respirator or did not complete the survey.

Summary statistics

Respondents' predominant characteristics were as follows: 64%, female; 71%, white ethnicity; 62%, over 40 years of age; 59%, married; and 69% had children (Table 1). The primary occupational position represented was (62%) registered nurses. Most respondents worked on (42%) medical/surgical wards, followed by (33%) the intensive care unit (ICU) and other settings (25%). Seventy-four (51%) respondents reported having last used a N95 respirator within the prior 2 months. Sixty-seven (50%) respondents stated they were last fit tested within 1 year. Of all respondents, 73 (49%) reported primarily wearing a duck bill N95 respirator, whereas 47 (32%) wore a cup-shaped N95.

Descriptive analyses

Comfort with N95 respirators. Twenty-four percent of respondents found their N95 respirator to be comfortable most of the time or always (Table 2). Thirty (20%) respondents stated that they rarely or never experienced an increase in facial temperature when wearing a N95 respirator, and 36% reported not having difficulty breathing while wearing a respirator. Thirty-two (22%) respondents reported rarely or never having difficulty verbally communicating with patients when wearing a N95 respirator. Among all respondents, only 6% reported that they would be able to tolerate continuously wearing a N95 respirator for an 8-hour shift.

Desired characteristics in a new respirator. Slightly more than half of respondents indicated that there was a need to create a new N95 respirator for HCWs (Table 3). In regards to fit testing, 31% of respondents reported wanting a N95 respirator that required fit testing. Forty-one percent of males preferred a respirator they could wear with facial hair. Social acceptability of respirators was preferred by 44% of respondents. When respondents were asked whether they would prefer wearing a reusable respirator versus a disposable respirator, 60% preferred a disposable respirator.

Multivariate analyses. Multivariate analyses were conducted to estimate the associations between several HCW characteristics and 2 respirator outcome variables. For the model focused on respirator comfort, the dependent variable represented a summation of the binary responses to questions 1 through 8 found in Table 2. Results from the ordinary least squares regression suggest that male sex and HCWs working less than 1 year in their current hospital unit were significantly associated with greater domain scores for comfort (Table 4). Logistic regression results that estimated the association between HCW characteristics and the desire for a new respirator found that emergency department staff had 12.3 greater odds of wanting a new respirator compared with their referent group ($P = .031$).

Table 2. Comfort with N95 respirators

Question		No. (%)*		
		1-2	3	4-5
1	Interferes with my ability to care for patients	82 (55.0)	50 (33.6)	17 (11.4)
2	Is comfortable to wear	81 (54.4)	32 (21.5)	36 (24.2)
3	Obstructs my vision	79 (53.0)	48 (32.4)	21(14.2)
4	Difficulty breathing through N95 respirator	53 (36.0)	50 (34.0)	44 (30.0)
5	Increases the temperature around my face	30 (20.4)	34 (23.1)	83 (56.4)
6	Leads to difficulty verbally communicating with patients	32 (21.5)	76 (51.0)	41 (27.5)
7	Leads to difficulty verbally communicating with coworkers	49 (32.9)	66 (44.3)	34 (22.9)
8	Causes skin irritation	110 (73.8)	19 (12.8)	20 (13.5)
9	I would be able to tolerate consistently wearing my N95 respirator, without removal, for an 8-hour shift, except for removal during normally scheduled breaks	129 (86.5)	11 (7.4)	9 (6)

*On a 5-point Likert scale, in which 1 = never, 2 = rarely, 3 = sometimes, 4 = most of the time, 5 = always.

Table 3. Desired characteristics in a new respirator

Question		No. (%)*		
		1-2	3	4-5
1	There is a need to create a new N95 respirator for health care workers	24 (16.1)	41 (27.5)	84 (56.3)
2	Prefer a N95 that is "socially acceptable" (ie, it does not frighten patients)	24 (16.2)	59 (39.9)	65 (43.9)
3	Prefer a N95 that does not require fit testing	46 (30.9)	38 (25.5)	65 (43.6)
4	Prefer a N95 that allows facial hair†	22 (14.9)	86 (58.1)	40 (27.0)
5	Instead of a disposable respirator, I prefer a reusable respirator	89 (60.1)	21 (14.2)	38 (25.7)
6	Prefer the maintenance (eg, disinfection) of my reusable respirator to be handled by my facility	95 (63.7)	16 (10.7)	38 (25.5)
7	Prefer the maintenance (eg, disinfection) of my reusable respirator to be handled by me	87 (58.4)	24 (16.1)	38 (25.5)
8	Prefer a reusable respirator that can be disinfected over a few seconds	99 (66.4)	21 (14.1)	29 (19.5)
9	Prefer a reusable respirator that can be disinfected over 2-5 minutes	108 (72.5)	20 (13.4)	45 (30.4)

*On a 5-point Likert scale, in which 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree.
†Respondents were asked to select neutral if not applicable.

DISCUSSION

Although respirator science has advanced since the CDC first issued recommendations about N95 use in health care, minimal research and development efforts have focused on the specific needs and preferences of HCWs. The purpose of this study was to assess HCWs' views about respirator use and the features they prefer to be included in the next generation of respirators.

In general, the results of this study support the position of the IOM[23] that the health care sector would benefit from respirator modification and development of one or more new respirators tailored to the unique needs of their workers.[48] The participants in this study reported experiencing numerous problems with contemporary respirators, including discomfort, difficulty breathing, lack of tolerability over an extended time period, and heat. Nearly 9 out of 10 respondents believed they would rarely or never be able to tolerate consistently wearing a N95 respirator for 8 hours, as might be required during a pandemic; however, the survey question did not ask respondents to estimate their tolerability in the event of a pandemic or exposure to a ''life-threatening'' infectious agent. These findings corroborate those from a recent clinical field assessment, which produced similar figures for certain respirator models.[30] If efforts shift toward building new respirators, it will be important to take into consideration the opinions expressed by the respondents of this survey: future respirators may be better tolerated if they are more comfortable, interfere less with breathing, diminish heat buildup, are disposable, and permit the user to have facial hair. Interestingly, only 44% of respondents reported they wanted a respirator that was socially acceptable, perhaps indicating that HCW safety is more important than the aesthetics of a respirator; or, it may suggest that the survey question needs to be validated. Further research is needed to explore this issue.

As public health and health care delivery organizations prepare for pandemics and other large scale infectious disease outbreaks, reusable respirator models are often on their lists of supplies to be stockpiled, as advised by numerous advisory and policy groups.[49-51] However, a majority (60%) of respondents in this survey reported that they prefer disposable models. This survey did not further explore whether the respondents' opinions would change if reusable models

Table 4. Multivariate analyses

	Dependent	Variable
	Comfort of respirator	Desire for a new respirator
Characteristics	Parameter estimate	Parameter estimate
Race		
African American	0.2	6.2*
Hispanic	1.2	0.3
Other race	1.1	1.6
Sex		
Male	1.2*	1.0
Age, yr		
18-29	−0.8	0.4
30-39	0.4	0.5
40-49	0.9	0.5
Children		
No children	1.1*	0.7
Highest level of education		
Bachelor's degree	−0.2	1.3
Master's/MD/doctorate	−0.7	0.6
Work setting		
ICU	−0.7	1.6
Emergency room	−0.7	12.3*
Other	0.5	1.3
Length of time in current unit, yr		
<1	1.5*	1.7
6-15	−0.4	3.6*
16+	0.1	1.7
Length of time in current specialty, yr		
<1	−0.2	0.5
6-15	0.8	0.3*
16+	0.2	0.6
Staff position		
Physician	0.6	3.2
Direct patient care†	0.2	0.7
Other	0.7	0.7

NOTE. Reference groups for variables are as follows: Race = white, sex = female, age = 50+years, children = have children, education = high school/diploma, work setting = medical/surgical, length of time in current unit = 1-5 years, length of time in current specialty = 1-5 years, staff position = registered nurse.
*$P < .05$.
†Direct patient care collapsed the following staff positions into 1 category: patient care assistant, dietician, respiratory therapist, physical therapist, occupational therapist, speech therapist, technician, and housekeeping.

were known to be more effective or more comfortable than disposable models or if they were faced with a global shortage of respiratory protective equipment during a public health crisis. Further investigation may help illuminate answers to some of these questions.

Multivariate analyses suggested that males found respirators to be more comfortable than females. If new respirators are developed, it will be important to consider the number of males and females in the sample population of HCWs that will be testing the new respirator models. The scientific literature indicates that sex differences do exist with comfort, and future research is needed to explore why females may find N95 respirators less comfortable to wear and how that could be remedied.[52,53] Furthermore, multivariate analyses also identified emergency department staff as more likely to want a new N95 respirator than their referent group. Prolonged respirator wear time, especially during influenza season, and interference with routine patient care and complex procedures may explain why emergency department staff are more likely to want a respirator that is comfortable and tolerable.[40]

There are 3 primary study limitations that merit attention. First, the overall response rate was 28%. This may have been due to the timing of the study because it was conducted during the winter holiday season or it may suggest that HCWs have little interest or no strong opinions about respiratory protection. Although a response rate of 28% may hamper the reliability of the results, response rates of less than 30% are quite common among health care provider surveys.[54-56] Voluntary participation may have biased the results, and, because the survey was anonymous, no data were collected on nonresponders. Furthermore, surveys were distributed to HCWs at the convenience of the unit manager. Future research is needed to address the reasons for nonresponse, and perhaps different research methods, such as focus groups or face-to-face interviews, would be more appropriate to assess HCW opinions about respiratory protection. Second, the study was limited to 2 sites in the same city, and the results may not be generalizable to a wider population. For example, because of the standardization of the national VA system, the results may be more representative of national VA HCWs than those in other settings. Third, the instrument used in this study has not been validated. Although the survey items were constructed using examples from the existing literature,[6,40,44-48] the construction of the questions may have altered the results.

CONCLUSION

The results from this study support the position of the IOM: that currently available respiratory protective equipment should be modified and new respiratory protective equipment should be developed to meet the specific needs of HCWs. The results suggest that HCWs favor respirators that are more comfortable, interfere less with breathing, diminish heat buildup, are disposable, and permit the user to have facial hair. Building new respirators equipped with features identified in this study may be one way of meeting the needs of HCWs and substantially increasing their acceptance of and compliance with prudent, contemporary respiratory protective measures. Completion of definitive clinical effectiveness trials may also positively

influence HCWs compliance and deserves further attention and resources.

The authors thank the participants for their participation in the survey and Norisse Tellman for her assistance with the distribution and collection of survey materials.

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