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Provider experiences with daily use of elastomeric half-mask respirators in health care

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Abstract

Background: During public health emergencies, demand for N95 filtering facepiece respirators (N95 FFRs) can outpace supply. Elastomeric half-mask respirators (EHMRs) are a potential alternative that are reusable and provide the same or higher levels of protection. This study sought to examine the practical aspects of EHMR use among health care personnel (HCP).

Methods: Between September and December 2021, 183 HCPs at 2 tertiary referral centers participated in this 3-month EHMR deployment, wearing the EHMR whenever respiratory protection was required according to hospital protocols (ie, when an N95 FFR would typically be worn) and responding to surveys about their experience.

Results: *Participants* wore EHMRs typically 1 to 3 hours per shift, reported disinfecting the respirator after 85% of the removals, and reported high confidence in using the EHMR following the study. EHMRs caused minimal interference with patient care tasks, though they did inhibit communication.

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DISCLAIMER

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ATTRIBUTION STATEMENT

N95 and NIOSH Approved are certification marks of the U.S. Department of Health and Human Services (HHS) registered in the United States and several international jurisdictions.

APPENDIX A. SUPPORTING INFORMATION

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.ajic.2024.01.015.

Discussion: HCP who had not previously worn an EHMR were able to wear it as an alternative to an N95 FFR without much-reported interference with their job tasks and with high disinfection compliance.

Conclusions: This study highlights the feasibility of the deployment of EHMRs during a public health emergency when an alternative respirator option is necessary.

Keywords

Elastomeric respirators; Respiratory protection program

BACKGROUND

During the COVID-19 pandemic, demand for respirators exceeded supply, requiring health care facilities to utilize alternative models that were unfamiliar to health care personnel (HCP) in some instances.¹ Elastomeric half mask respirators (EHMRs) are an alternative to traditional N95 filtering facepiece respirators (N95 FFRs) because they are reusable and may be configured to provide the same or higher levels of protection.^{2,3} While EHMRs are listed as a respirator option for health care in the Centers for Disease Control and Prevention Hospital Respiratory Protection Program (RPP) Toolkit,⁴ they are not commonly utilized.⁵ Incorporating EHMRs into a RPP as an alternative to an N95 FFR will require that health care facilities have the capacity to fit test and effectively train their HCP on the respirator and that HCP will be able to properly disinfect, store, and tolerate wearing the EHMR during their shifts.

Previous research has shown that rapid fit testing and training on EHMRs is feasible in a public health emergency scenario.^{6,7} Disinfection is achievable, with a variety of effective methods including the use of regular disinfectant wipes that are readily available on hospital units.⁸⁻¹⁰ The remaining aspects of EHMR implementation success require understanding how HCPs feel about EHMRs and the ease with which they can use them during patient care.

The purpose of this study was to evaluate the success of an EHMR deployment in terms of rapid and effective fit testing and training, the ability of participants to wear the respirator during routine patient care activities, and participant adherence to disinfection protocols among 2 cohorts of HCP. Understanding the experience of HCP utilizing EHMRs as an alternative to N95 FFRs for patient care will provide context for the feasibility of incorporating these respirators into RPPs within health care facilities, which may better prepare health care facilities for future airborne disease outbreaks.

METHODS

This study occurred from September to December 2021 at 2 adult health care facilities, Hospital A, a 733-bed facility, and Hospital B, a 1,082-bed facility, in collaboration with the National Personal Protective Technology Laboratory within the National Institute for Occupational Safety and Health, part of the Centers for Disease Control and Prevention. HCPs were recruited into this study and wore a Honeywell North RU8500 Half Mask

respirator (Honeywell International Inc); a silicone respirator with a speech diaphragm that comes in multiple sizes and is fitted with Honeywell North 7580P100 filter cartridges. This respirator was chosen because (1) the exhalation valve cover keeps air from being exhaled into a patient's breathing zone, (2) filter covers prevent potential liquid splashes from reaching the filter material, (3) the silicone body is easy to clean and disinfect, and (4) the speech diaphragm facilitates clearer communication from the wearer.¹¹ HCPs wore these respirators during routine patient care when respiratory protection was required by hospital protocols (ie, when an N95 FFR would normally be worn).

Participants were surveyed on aspects of EHMR use and were incentivized up to \$450 based on the number of surveys they completed out of 7. This study received human subjects' approval from the Institutional Review Boards at The University of Texas-Health Science Center in Houston, Baylor College of Medicine (HSC-SPH-21-0164), and Emory University (STUDY00003014).

Recruitment

HCP were eligible to participate if they were at least 18 years of age, had been fit tested to wear a respirator in the prior 2 years, regularly wore a respirator or mask to care for patients in the prior year, and provided direct patient care. HCPs that reported having loss of smell or taste during recruitment were excluded from the study given the assumption that they would not be able to detect Bitrix, the fit testing solution which was used to qualitatively fit test workers prior to respirator use. They were also excluded if they had facial hair or a facial injury or adornment that would interfere with the seal of the respirator.

At Hospital A, HCP from a general medical ward and an intensive care unit (ICU) were enrolled. Nurses in leadership roles were recruited and educated to serve as experts on the use of EHMRs, reminding participants to wear the EHMR and alerting the study team about low supplies. Participants from Hospital A included nurses, certified nursing assistants, and patient care assistants. At Hospital B, recruitment was targeted to HCPs working on inpatient units that were more likely to have patients with aerosol-transmissible diseases (ie, emergency department, ICU). Participants included a variety of HCPs from around the hospital including those that float across units.

Training

HCPs at both sites accessed a REDCap survey that included a 10-minute video about EHMR use, a screening survey, and a consent form. HCPs who met the eligibility criteria and completed the consent form then signed up for an appointment to be fit tested and trained on EHMR use.

During the appointments, participants received their EHMRs, were fit tested using an Occupational Safety and Health Administration-approved qualitative fit testing method,¹² and received face-to-face training on how to disinfect the respirator, including placement of the pediatric mask over the exhalation valve (Fig 1). Placement of the pediatric mask over the exhalation valve was required by the infection prevention teams due to the lack of a filter on the valve and is considered a safe practice.¹³ At Hospital A, participants received additional training during an in-service session on their units led by the nurse leaders. At

Hospital B, the full training occurred at the same time as fit testing during a 60-minute session where participants also watched a 10-minute video about EHMR use.

Study logistics

Participants were instructed to disinfect the respirator every time they removed it using Oxivir Tb wipes. These wipes and disinfection methods were chosen based on our previous study on disinfection efficacy.¹⁴ Hospital A provided disinfection stations that included wipes, pediatric masks, and a surface for cleaning. Participants were instructed to only use the study-provided wipes for cleaning their EHMRs. Because participants were dispersed across the hospital at Hospital B, the study team did not provide disinfection stations. Study coordinators left wipes on the units and with central supply distribution. Both sites provided participants with drawstring bags to store their EHMRs during their shifts when they were not using them. Replacement parts for the respirators were available upon request from the study staff. Participants were given drawstring bags to store their respirators in when they were not using them.

Data collection

Participants completed a total of 7 surveys: a baseline survey, 5 biweekly surveys, and a terminal survey (see Supplemental Material for surveys). The baseline survey included questions about participants' prior experience with respirators and their comfort level with completing activities related to the EHMR (inspection, donning, seal checks, doffing, and cleaning) following training. Every 2 weeks during EHMR deployment, participants were surveyed about their EHMR use, adherence to disinfection protocols, and limitations experienced by the use of EHMRs in lieu of N95s.

The terminal survey was completed 2 weeks following the end of the deployment and included the same questions as the baseline survey, as well as open-ended questions about participants' overall experience with the EHMR, what they liked and did not like about it, and what they would change about it. Additional data were collected regarding participants' physical comfort wearing the EHMR and comparing the EHMR comfort with the N95 FFR, which is reported elsewhere.¹⁶

Data analysis

Following the completion of the 3-month deployment, survey responses were compiled. Only participants who completed both the baseline and terminal surveys are included in analysis as we are comparing results from the 2 surveys. Descriptive analysis was utilized to describe the characteristics of study participants and their EHMR use. Differences between categorical measures were examined using the Mantel-Haenszel χ^2 test. Analyses were completed using R Software (Version 4.1.2). These analyses were conducted by site as well as aggregated. Qualitative data from the open-ended questions were categorized into themes and summarized to provide additional context.

RESULTS

A total of 208 HCPs were enrolled in the study and completed the baseline survey, 98 from Hospital A and 110 from Hospital B. 183 HCPs completed both the baseline and terminal surveys and were included in the analysis—73 from Hospital A and 110 from Hospital B. Most participants were female (74%) and the most common job title was nurse (52%) (Table 1). Participants worked in a variety of units with the largest number coming from the ICU. Only 2% had worn an EHMR for work during the pandemic prior to the deployment.

Wear time and job interference

Most participants wore the EHMR for an average of 1 to 3 hours per shift, with the longest consecutive time spent wearing the respirator without removal being less than 3 hours for most participants. Chi-square tests revealed that the average amount of time spent wearing the EHMR significantly decreased across study weeks ($P < .001$), but consecutive wear time did not significantly change ($P = .084$).

Participants were given a list of job tasks and asked whether they had difficulty performing them while wearing the EHMR in the past 2 weeks. They were also given the option to select “did not perform” for tasks they had not completed in this period. The number of times the task was reported as being completed was tallied, as was the number of times participants identified the task as difficult to complete while wearing the EHMR. These instances were then totaled across all biweekly surveys (Table 2). The most frequently reported challenge was communication with patients and their families, reporting this as a challenge 50% of the 688 times it was performed. Performing a swallowing exam was reported as challenging 22% of the time and moving or repositioning the patient 11% of the time. These challenges were reported at similar frequencies at each biweekly survey. Some frequently performed tasks that were not challenging to perform while wearing an EHMR include performing physical exams (9%), bathing or feeding a patient (6%), and changing wound dressings (4%).

Training

Participants at Hospital B felt comfortable completing all EHMR activities in the baseline survey, while those at Hospital A felt very uncomfortable (Fig 2). Terminal survey comfort levels did not differ between the 2 sites (all $P > .05$) with nearly 100% of the participants feeling comfortable with all tasks. There was a slight decline in comfort levels at Hospital B from the baseline to the terminal survey.

Disinfection

109 (99%) participants at Hospital B felt comfortable disinfecting the EHMR at the baseline survey. At the terminal survey, 176 (96%) participants across both sites felt comfortable disinfecting the EHMR, with participants feeling equally comfortable disinfecting at Hospital B ($n = 105$, 96%) and Hospital A ($n = 71$, 97%).

Over the 5 biweekly surveys, participants reported disinfecting the EHMR after removal an average of 85% of the time, which did not statistically differ over the study weeks (P

= .90), or between sites overall ($P = .28$). When asked about challenges with disinfection, participants at Hospital B reported sometimes or always not having access to disinfectant wipes ($n = 159$, 38%) more often than those at Hospital A ($n = 43$, 12%), $P < .0001$ (Table 3). Over the 5 surveys at Hospital B, there was a significant improvement in wipe access ($P = .002$), with 76% reporting always having access at week 10. The other most common reason for not disinfecting was that disinfection and drying took too long, with participants reporting this as a problem some or all of the time in 35% of survey responses.

Other participant feedback

When asked why they decided to participate in the study, participants described wanting an alternative respirator to the N95 FFRs they had been reusing during the COVID-19 pandemic for either improved comfort (reported by 25% of the participants), safety (33%), or reusability (14%).

When asked to elaborate on challenges they faced wearing the EHMR, 42 participants pointed out that it was difficult for colleagues and patients to hear them even with the speech diaphragm. One participant reported feeling that they had “*to almost shout to be heard at times*” and an additional challenge with the “*tiredness that [shouting] causes*.” 14 participants reported issues with compatibility of wearing the EHMR with glasses or goggles and suggested including a notch at the nose piece where the glasses could sit. 22 participants felt that the EHMR was bulky and suggested a less imposing design that was easier to carry around, weighed less, and was less “*attention grabbing*,” while others recommended printing pamphlets to inform patients and their families about the EHMR so that they would know what to expect.

Constant disinfection was a challenge cited by 39 participants. Participants were instructed to disinfect the EHMR after every removal. One participant explained, “*the cleaning process is too long especially if you clean between each patient*,” and another pointed out that the drying process is difficult “*when you get another patient unexpectedly*.” Suggestions for improvement included alternative options for disinfection, such as machines that can sterilize EHMRs quickly, a disinfectant spray, or faster drying wipes. Another common complaint was the requirement to use pediatric masks over the exhalation valve with many feeling that using these masks reduces the sustainability of the EHMR. This is no longer recommended as the availability of EHMRs without exhalation valves has increased.

DISCUSSION

During a 3-month deployment, HCPs who had not previously worn an EHMR were able to be successfully fit-tested and trained on the EHMR and were able to wear it as an alternative to an N95 FFR without much reported interference with job tasks and with high disinfection compliance (disinfecting after removal 85% of the time).

Given some differences in implementation between the 2 study sites, we were able to compare between sites to better understand participant challenges and make recommendations for improvement in future deployments. One difference between sites was training. Hospital B provided one-on-one trainings to participants at the time of fit

testing, similar to our previous study,⁶ while Hospital A provided some one-on-one training but relied mainly on in-service trainings on the health care units. Unfortunately, because the survey was available online at the time of fit testing, many participants at Hospital A took the baseline survey before completing the in-service training, making it difficult to compare the success of the in-service training. This is likely why the baseline survey results for comfort levels with EHMR activities were so low for Hospital A participants. For future deployments, health care leadership must plan and prepare for training so that it can be quickly implemented in a way that allows HCPs to feel comfortable and safe using their EHMRs for patient care.

Another difference between sites was the use of disinfection stations. Because Hospital A recruited whole units into the study, the study team was able to provide disinfection stations on the units. Hospital B recruited from across the hospital and included HCP that float between units, making it impossible to provide every participant with a disinfection station. Participants at Hospital B reported not having access to disinfectant wipes more often than those at Hospital A at the beginning of the deployment and reported a lower disinfection rate, though not significantly different. A study on disinfection compliance among a different group of HCP assigned to use EHMRs similarly found that compliance is lower among workers without fixed workstations due to a lack of convenience and exclusion of EHMRs in the “safety culture” of the hospital.¹⁵ Access to disinfectant wipes and a place to set the EHMR down as HCP disinfect therefore appears to be an important component of an EHMR deployment plan. These disinfection stations could also be utilized to clean face shields, goggles, and other equipment. Future research could also include periodic cleaning quality assessments to supplement the self-reported disinfection measures.

One persistent challenge with the EHMR was difficulty in communication with colleagues and patients, and issue that has been highlighted in other user acceptance studies.^{16,17} While the EHMR used in this study was chosen partly for its speech diaphragm, it did not work well enough to allow for easy communication, leading participants to suggest improved designs. The use of a procedural mask over the exhalation valve may have further reduced the speech intelligibility, as seen in previous research.¹⁸ There are now several NIOSH-approved EHMRs that do not have an exhalation valve or have adapters available to filter exhaled breath exiting through the valve.

The type of EHMR deployed is clearly an important consideration when planning for a deployment. Prior to the COVID-19 pandemic, EHMRs were not commonly used in health care, and only a few studies have been conducted on their use in this setting.⁵ Health care administrators need to be cognizant of the potential challenges identified in this study and stockpile EHMRs that address these issues. Another important consideration is the storage of the respirators.¹⁹ We asked participants where they typically stored their EHMR in between uses, but received responses referencing storage both in between and during shifts, rendering the data difficult to discern. Participants were given drawstring bags in which to store their EHMRs during their shift but were not given a location to store the respirators when they were not working. It may be helpful in future deployments to provide a cubby or some other form of storage where HCPs can leave their respirators when they are off shift

and not have to worry about losing them or leaving them in hot cars where the EHMR may get damaged.

The strengths of this study include the large number of HCPs who wore EHMRs for patient care during the COVID-19 pandemic providing real-world data on the use of EHMRs during public health emergencies. Participants represented a variety of HCPs in terms of occupation and type of work department, and EHMR use fluctuated throughout the deployment as would likely be the case in future deployments. The deployment methods varied slightly between the 2 study sites, providing additional comparisons to determine best practices for EHMR deployment. A study limitation is that we only tested 1 model of EHMR and identified the benefits and challenges of using it in health care. Further research needs to be done on other EHMR models to determine which is best for HCP use.

CONCLUSIONS

Overall, the EHMRs used in this study were well-received by participants, did not interfere drastically with patient care tasks, and were disinfected at a high rate after removal. One-on-one training may have improved HCP comfort with using the EHMR and providing disinfection stations on the unit may have improved disinfection compliance, though providing alternative disinfection options could also be useful in future deployments. The success of this study demonstrates the feasibility of the deployment of EHMRs to HCP during a public health emergency when an alternative respirator option is necessary. These alternative respirators could also be used in routine patient care where an FFR is required and may be preferred for their comfort and reusability.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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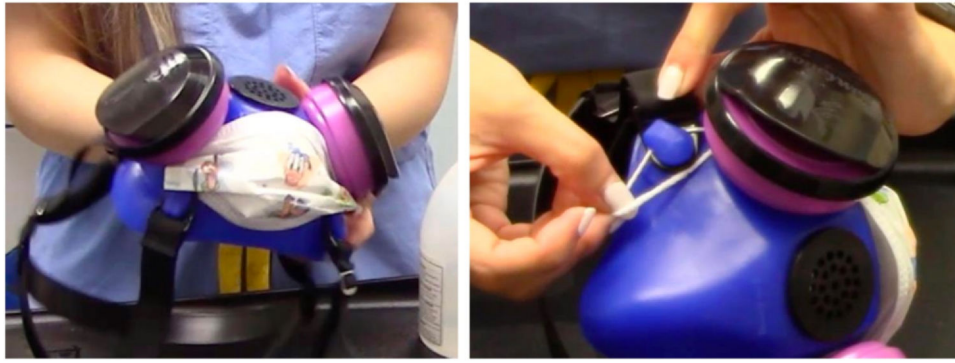


Fig. 1. Placement of the pediatric mask over the exhalation valve. This practice is no longer recommended by NIOSH as elastomeric respirators without exhalation valves are now readily available.

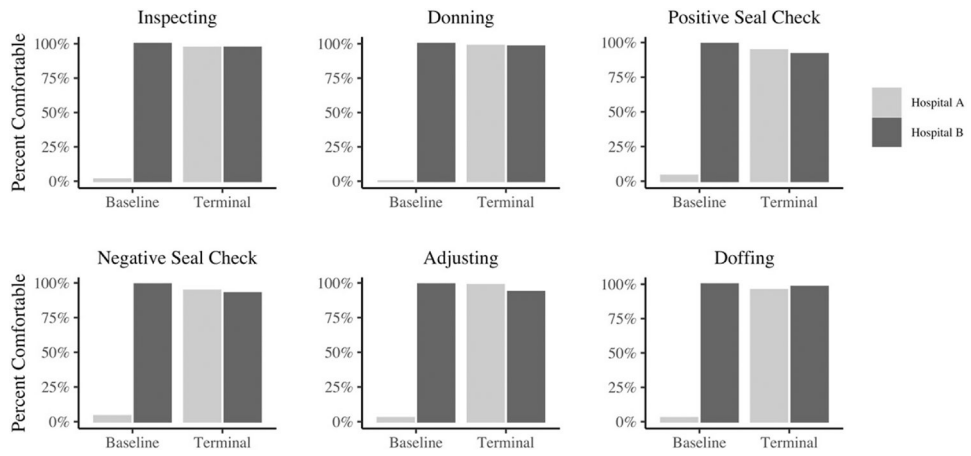


Fig. 2. Percentage of participants who reported feeling comfortable or extremely comfortable performing the 6 EHMR activities at the baseline and terminal surveys by study site.

Table 1

Demographics of the participants from both sites, reported by site and aggregated

Demographic	Total	Hospital A	Hospital B
Age	N (%)	N (%)	N (%)
18-25	38 (21)	27 (37)	11 (10)
26-35	76 (42)	22 (30)	54 (49)
36-45	31 (17)	5 (7)	26 (24)
45-55	21 (12)	12 (16)	9 (8)
> 55	17 (9)	7 (10)	10 (9)
Self-described sex			
Female	136 (74)	59 (16)	77 (70)
Male	44 (24)	12 (16)	32 (29)
None of these	3 (2)	2 (3)	1 (1)
Race			
American Indian or Alaska Native	5 (3)	2 (3)	3 (3)
Asian	42 (23)	24 (33)	18 (18)
Black or African American	31 (17)	15 (21)	16 (16)
Native Hawaiian or Other Pacific Islander	1 (1)	1 (1)	0 (0)
White	101 (55)	29 (40)	72 (71)
More than one race	3 (2)	2 (2)	1 (1)
Hispanic Ethnicity			
Yes	28 (15)	4 (5)	24 (22)
No	155 (85)	69 (95)	86 (78)
Education			
High school/GED/	5 (3)	3 (4)	2 (2)
Tech/certification program	9 (5)	5 (7)	4 (4)
Associate's degree	23 (13)	7 (10)	16 (15)
Bachelor's degree	96 (53)	53 (73)	43 (39)
Master's degree	34 (19)	5 (7)	29 (26)
Doctoral (MD/PhD)	16 (9)	0 (0)	16 (15)
Job Title			
Patient Care Assistant/Patient Sitter/Lift Team Technician	17 (9)	10 (14)	7 (6)
Nurse	95 (52)	63 (86)	32 (29)
Physician/Physician Assistant/Nurse Practitioner/CRNA/Med Student	18 (10)	0	18 (16)
Respiratory Therapist /Ultrasound Neurology	18 (10)	0	18 (16)
Occupational Therapist/Assist/Physical Therapist/Asst./Speech Path	31 (17)	0	31 (28)
Other	4 (2)	0	4 (4)
Work Department			
Emergency Department/Trauma	17 (9)	0	17 (15)
Intensive Care Unit (ICU)	104 (57)	61 (84)	43 (39)
Operating Room	4 (2)	0	4 (4)
Float (GM/ICU)	40 (22)	0	40 (36)

Demographic	Total	Hospital A	Hospital B
General Medicine (GM)	15 (8)	12 (16)	3 (3)
Other	3 (2)	0	3 (3)
Prior Respirator and Mask Use (not mutually exclusive)			
Surgical/Procedural Mask	155 (85)	58 (79)	97 (88)
N95 FFR	136 (76)	54 (74)	82 (75)
EHMR	4 (2)	2 (3)	2 (2)
Powered Air-Purifying Respirator (PAPR)	5 (3)	4 (5)	1 (1)
Controlled Air-Purifying Respirator (CAPR) Powered Air-Purifying Respirator	1 (1)	1 (1)	0
Completed Biweekly Surveys			
Biweekly 1	180 (98)	71 (97)	109 (99)
Biweekly 2	172 (94)	68 (93)	104 (95)
Biweekly 3	180 (98)	70 (96)	110 (100)
Biweekly 4	178	70 (96)	108 (98)
Biweekly 5	175	70 (96)	105 (95)

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Table 2

Frequency with which each patient care task was reported as a challenge when it was performed while wearing the EHMR throughout the entire deployment period

Task	Total number of times the task was performed	Total number of times task was reported as being a challenge while wearing EHMR (%)
Communication		
Talking with patients/family	688	344 (50)
Aerosol Generating Procedures		
Oral Suctioning	484	22 (5)
Administering oxygen *	71	8 (11)
Intubation *	74	4 (5)
PEG/Feeding tube placement *	9	0 (0)
Bronchoscopy *	53	0 (0)
Moving Patient		
Moving/repositioning patient	580	63 (11)
Assisting patient with walking	279	20 (7)
Patient transports	382	18 (5)
Other		
Swallowing exam *	27	6 (22)
Performing physical assessment/exam	643	55 (9)
Assisting with a medical procedure	299	22 (7)
Bathing/feeding a patient	457	25 (6)
Starting IV or arterial line	319	20 (6)
CPR	165	11 (7)
Medical procedure *	85	5 (6)
Dressing a patient	422	20 (5)
Tracheostomy care *	193	9 (5)
Taking vital signs	506	23 (5)
Distributing medication	369	16 (4)
Changing dressing	328	12 (4)
Drawing blood	354	12 (3)
Placing leads for ultrasound *	3	0 (0)
Performing ultrasound *	3	0 (0)

NOTE. *Only asked at Hospital B because of differences in occupation of participants.

Table 3

Frequency of reported challenges to disinfection at each hospital

Disinfection issues	Frequency	Percentage of times reported (Hospital A)	Percentage of times reported (Hospital B)
I did not have access to disinfection wipes	None of the time	87%	62%
	Some of the time	7%	30%
	All of the time	6%	8%
The disinfection and drying takes too long	None of the time	81%	51%
	Some of the time	19%	38%
	All of the time	0%	11%
The wipes irritate the skin on my face	None of the time	87%	83%
	Some of the time	13%	14%
	All of the time	0%	2%
The wipes irritate the skin on my hands	None of the time	96%	93%
	Some of the time	4%	6%
	All of the time	0%	1%
The odor from the wipe irritates my lungs/breathing	None of the time	81%	84%
	Some of the time	17%	14%
	All of the time	2%	2%