Bacterial Contamination of Military and Civilian Uniforms in an Emergency Department

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CE Earn Up to 8.0 Hours. See page 229.

Contribution to Emergency Nursing Practice

- The current state of scientific knowledge on the bacterial contamination of military and civilian personnel uniforms within a military emergency department is nonexistent.
- The main finding of this research is that all personally owned uniform variations were significantly more colonized by bacterial specimens compared with hospital-provided scrubs.
- Personally owned hospital uniforms of various types pose a greater risk for bacterial contamination in the emergency department than hospital-provided scrubs.

Abstract

Introduction: The emergency department is a fast-paced, high-volume environment, serving patients with diverse and evolving acuities. Personnel providing direct care are continually exposed to pathogenic microorganisms from patients and everyday surfaces, to which the organisms may spread. Indeed, hospital items—such as electronic devices, stethoscopes, and staff clothing—have demonstrated high rates of contamination. Despite this, policies governing the use, disinfection, and wear of various environmental surfaces remain relaxed, vague, and/or difficult to enforce. This study aimed to examine the bacterial contamination on 2 hospital uniform types in a large military hospital within the emergency department.

Methods: Environmental sampling of military and civilian nursing staff uniforms was performed on 2 separate occasions. Emergency nurses wore hospital-provided freshly laundered scrubs on the first sampling day and home-laundered personally owned uniforms complicit with ED policy on the second sampling day. Samples were collected by impressing of contact blood agar growth medium at arrival (0 hour), 4 hours, and 8 hours of wear. Microbiological methods were used to enumerate and identify bacterial colonies.

Results: Bacterial contamination of personally owned uniforms was significantly higher than freshly laundered hospital-provided scrubs on 4 different sampling sites and across the span of an 8-hour workday. No significant differences were observed between military and civilian personally owned uniforms. However, several risk factors for nosocomial infection were increased in the military subgroup.

Discussion: Re-evaluating organizational factors (such as uniform policies) that increase the propensity for pathogenic contamination are critical for mitigating the spread and acquisition of multidrug-resistant organisms in the emergency department.

Key words: Infection prevention; Emergency department; Military nursing; Hospital uniform; Bacterial contamination

Hospital acquired infections (HAIs) affect approximately 1.7 million people in the United States[1] and increase postdischarge mortality.[2] Patients who contract multidrug-resistant organism (MDROs) infections are not only more susceptible to postdischarge mortality but also to costly readmissions and additional ED visits.[3] Important research has elucidated that the risk of MDRO contamination is abundant on environmental surfaces and equipment in the immediate vicinity of colonized patients and that health care personnel play a key role in the transmission of culpable microorganisms.[4,5]

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Some of the unique elements that have been proposed to contribute to HAIs in the emergency department include its fast-paced, high-volume nature, as evidenced by 130 million visits comprising nearly 50% of all hospital admissions annually.[6,7] Various studies have described poor cleaning and high bacterial contamination of everyday clinical items within the emergency department including stethoscopes,[8] computer mice, keyboards,[9,10] and ultrasonographic probes[11], with MDRO prevalence (specifically, methicillin-resistant *Staphylococcus aureus* [MRSA]) as high as 42%. To address the problem of HAIs in the emergency department, it is important to identify risk factors for pathogenic contamination and transmission. Existing approaches have focused on improving substandard adherence to hand hygiene (considered the foremost intervention against HAIs[12]), estimated at only 30%[13,14] in the emergency department, and improved adherence to recommended laundering guidelines for health care apparel.[15,16]

The attire of health care personnel has been proposed as a vector of infectious organisms.[17,18] Not only are nurses particularly susceptible to colonization (up to 37% reporting splash exposures to blood or other bodily fluids in a military hospital),[19] but microorganisms can survive on the cotton and polyester fabrics of the medical uniform for up to 98 days.[20] Evidence suggests significant colonization across diverse uniform types (lab coats, scrubs, others).[21,22] To date, however, no studies have specifically identified colonization rates or behavioral risk factors of ED personnel uniforms, specifically.

The aims of this study were to characterize the bacterial contamination of emergency nursing personnel uniforms in a large military hospital. Two uniform types were specifically investigated: hospital-provided scrubs and personally owned uniforms (including military service uniforms and permissible scrubs owned by staff). In addition, differences in bacterial contamination between military and civilian personnel were assessed. Finally, bio-behavioral correlates, including hand-hygiene and laundering patterns, were investigated as contributors to microbial contamination of the health care uniform.

Methods

STUDY DESIGN

Active duty and civilian nursing staff (medic, LPN, RN, APRN) in the emergency department were eligible for inclusion in the study. Participants were excluded if they were not in a direct patient-care role or if they only wore hospital scrubs. In total, 58 eligible nursing staff members were enrolled, and 50 completed both sampling days. Eight participants did not complete the study, mostly because of relocation prior to completing sampling; 1 participant was excluded from analysis because of a sampling error. All incomplete data were coded as "missing" during analysis. The study was approved by the Institutional Review Board of the facility, and informed consent was obtained from each participant. This study was a continuation of a larger inpatient-focused study of hospital uniform microbial contamination. A *post hoc* power analysis showed that, in our sample, the study had 80% power to detect a 60% difference in bacterial levels between scrubs and military uniforms for each location and time. This is based on a power analysis for a paired Students' *t*-test on log counts, assuming a standard deviation of 1.2 on the difference for the logged data.

We performed an experimental crossover study for enrolled participants within the emergency department of a large military medical center in the Pacific. All participants were sampled in hospital-provided scrubs first. Clean hospital scrubs (55% to 45% cotton to polyester, top and pants) were provided in a sealed pouch before the day of sampling. Personally owned uniforms included long-sleeved active duty uniforms (50% to 50% cotton to nylon), a handful of short-sleeved variations (sleeves rolled up or military-approved camouflage scrub top), and any approved style of civilian scrubs. Participants were not given special instructions for laundering or wear of their personal uniform before the day of sampling. Sampling occurred between June 2017, and February 2018. Proportion of participants sampled during a day, mid-, and night shift were 57%, 9%, and 34%, respectively, for hospital-scrub sampling and 70%, 7%, and 23% for personally owned uniform sampling.

DATA COLLECTION

Replicate Organism Detection and Counting (RODAC) plates (Contact I Blood Agar, Remel, Lenexa, KS) were used for the detection of live microorganisms. Each participant was sampled by RODAC impression method twice: once in each of the uniforms of interest. Samples were collected from each participant at (1) the sleeve cuff of the dominant hand, (2) waistline/pocket area of the dominant hand, (3) front abdominal area, and (4) lower back area. In addition, the volar surface of both wrists was sampled. Sampling was performed by 2 trained research coordinators between 0600 and 0700, 1000 and 1100, 1400 and 1500 for day shifts; 1100 and 1200, 1500 and 1600, 1900 and 2000 for mid-shifts; 1800 and 1900, 2200 and 2300; 0200 and 0300 for night shifts. Contact plates provided a 60-mm (diameter) coverage of the targeted sampling regions, and care was taken throughout the day to approximate the same area each time, using visual landmarks. Owing to scheduling variability, the interval between sampling days varied; however, sampling was typically completed within the same week.

RODAC agar was impressed against the test surface for 5 seconds. All plates were incubated at 35° to 37° C (95° to 98.6°F) for 24 hours. Plates were observed for growth and the number of colony forming units (CFUs) was recorded using a PROTOS[3] automated colony counter (Synbiosis, Frederick, MD). Standard clinical microbiological methods and VITEK 2 were further used to identify pathogenic organisms. During bacterial sampling, a brief oral survey was administered to collect information regarding hand-hygiene frequency and perceived barriers as well as laundering history of personally owned uniforms.

STATISTICAL ANALYSIS

Repeated-measure, mixed-effects models were developed to assess CFU counts from the 2-period, 2-factor crossover design. Separate models were run at each sampling location to assess CFU differences between personally owned uniforms and hospital-provided scrubs. The models also examined the effect of time of sampling (0, 4, and 8 hours), and the interaction between time of sampling and type of uniform. Carryover effects were assessed and found to be nonsignificant. CFU data were transformed to the log scale after adding 1 to account for 0s (<1% of data), to enhance normality. Descriptive results are presented as mean and standard deviation as well as median and interquartile range (IQR). Bar lines in the figures indicate ± 95% upper and lower bounds on the median. The ratio for comparing levels between personally owned uniforms and hospital-provided scrubs was based on the ratio of geometric means. Significance was statistically meaningful at a P value of 0.05 for all analyses, which were conducted using SAS software version 9.4 (SAS Institute, Cary, NC).

Results

PARTICIPANT CHARACTERISTICS

The median age of military personnel participating in the study was 30 (25 to 38) years, whereas the median age of civilian personnel was significantly higher ($P < 0.001$) at 41 (35 to 48) years. Female staff made up 55% of the study population, and male staff members contributed 45%. Among the military staff, 42% were women, and 58% were men; women comprised 73% of the civilian population and men 27%. These gender differences are typical of the military and civilian nursing workforce. Nursing experience of military staff was 60 (36 to 94) months, significantly lower than civilian experience at 131 (90 to 240) months ($P < 0.001$) (Table 1). Hand-hygiene frequency was reported on both sampling days, with high concordance (Table 2).

Comparison of Bacterial Colonization of Personally Owned Hospital Uniforms and Hospital-Scrubs

Evaluation of personally owned uniforms and hospital-scrubs across a mixed military and civilian population revealed significant differences in bacterial contamination at 4 different sites (Figure 1). Significance was meaningful upon arrival to work at the abdomen, sleeve cuff, waist pocket, and back. Colonization of the personally owned uniforms remained significantly higher over the course of the workday, even as hospital-provided scrubs accumulated bacteria. Interestingly, as hospital-provided scrubs showed a pattern of bacterial accumulation, personally owned uniforms observed a variety of fluctuations throughout the 8-hour workday. Personally owned uniforms displayed the highest median CFUs at the sleeve cuff and waist pocket across all sampling time points. In contrast, hospital-scrub wearers shared the highest rates of contamination (~20 CFU) across the abdomen, sleeve cuff, and waist pocket across all sampling time points. Overall, colonization of personally owned uniforms at the waist and cuff were ~4.9 and 7 times higher than hospital-provided scrubs, respectively, on arrival. After 8 working hours, personally owned uniforms at the waist and cuff remained about 4 and 3.5 times higher colonization than hospital-provided scrubs. Personal uniforms were also 4.2 times greater at the back, and ~3.3 times greater at the abdomen on arrival, a difference that fell to 2 and ~1.8 times after 8 hours. Differences between the 2 populations were also observed at the left and right volar surface upon arrival and at 8 hours (Supplementary Figure 1), likely related to the wear of watches and other items on the left wrist.

Assessment of Risk Factors for Bacterial Colonization

Investigation of personnel subgroups (civilian versus military) indicated no significant differences in bacterial contamination at any sampling location or at any time point (Figure 2). Both subgroups demonstrated the highest degree of colonization at the cuff and waist pocket and the lowest at the abdomen and back. Trends for colonization at the sleeve cuff were nearly twice as high in military personnel compared with civilian, although this was not statistically

TABLE 1
Demographic and behavioral characteristics among military and civilian staff in an emergency department

	Emergency department: combined		ED military		ED civilian	
	n	%	n	%	n	%
All	53	100	31	100	22	100
Age						
20-24	11	21	11	35	0	0
25-29	14	26	12	39	2	9
30-29	15	28	7	23	8	36
40+	13	25	1	3	12	55
mean (standard)	32.8 (9.7)		27.1 (5.3)		40.8 (8.7)	
median (IQR)	30 (25-38)		26 (23-30)		41 (35-48)	
Gender						
Female	29	55	13	42	16	73
Male	24	45	18	58	6	27
Experience (months)						
0-36	11	21	8	26	3	14
37-72	15	28	13	42	2	9
73-120	12	23	7	23	5	23
121+	15	28	3	10	12	55
mean (standard)	106 (91)		66 (46)		162 (108)	
median (IQR)	84 (48-135)		60 (36-94)		131 (90-240)	
No. times military or personal uniform worn previously						
0	30	57	16	52	14	64
1	13	25	6	19	7	32
2	6	11	5	16	1	5
3-5	4	8	4	13	0	0

significant. However, no differences in bacterial colonization were found between subgroups for times uniform was worn before washing (Supplementary Table 1). In regard to hand hygiene, nurses performed this task 10 (6 to 15) times per hour. Civilian personnel reported approximately 4 more hand hygiene events per patient hour ($P = 0.008$) than military staff (Table 2); this difference remained when controlling for age.

Discussion

Little is known on the role of health care uniforms as bacterial vectors in a military facility. At present, uniform regulation across US hospitals varies greatly, particularly in military hospitals, which often require active duty personnel to wear the military uniform or an approved modification of the uniform during work hours. This variability of health care textiles and associated behavioral factors resulting from relaxed uniform policies differs significantly from the more regulated and streamlined polyester/cotton hospital-provided scrubs. Whether these differences contribute meaningfully to the risk of bacterial colonization and transmission is not well understood.

This study revealed important demographic considerations across a military hospital emergency department. On average, civilian staff members were considerably older and more experienced than military participants. This is likely attributable to the preferential placement of more experienced civilian nurses in the emergency department and the assignment of young medics who were assigned to this facility following their initial military training.

In this sample, we report that personally owned hospital attire, whether military or civilian, harbored

TABLE 2
Hand-hygiene frequency of military and civilian ED personnel

	Emergency department: all		ED: military		ED: civilian	
	n	%	n	%	n	%
Handwashing hygiene - M						
1-5	13	25	11	35	2	9
6-10	26	49	16	52	10	45
11-20	11	21	2	6	9	41
>20	3	6	2	6	1	5
mean (standard)	10.9 (8.3)		9.2 (9.1)		13.4 (6.5)	
median (IQR)	10 (6-15)		6 (5-10)		10 (10-15)	
Hand-hygiene frequency - S						
1-5	11	21	9	29	2	9
6-10	22	42	12	39	10	45
11-20	17	32	8	26	9	41
>20	3	6	2	6	1	5
mean (standard)	11.4 (8.0)		10.0 (8.6)		13.4 (6.7)	
median (IQR)	10 (6-15)		6 (4-12)		10 (10-15)	

M, military or personal uniform worn at the time of survey response; S, hospital-provided scrubs worn at the time of survey response.

significantly more bacteria than hospital-provided scrubs. Variations in uniform style (eg, sleeve length), uniform area, and time of sampling did not affect that difference. Although no previous study has described or compared the bacterial load of personally owned uniforms in a military emergency department, comparable studies have reported differences between white coats and regulated hospital scrubs. Two studies concluded that uniform type did not have impact on the rate of bacterial colonization,[22,23] although another reported that pathogenic contamination on long-sleeved coats was significantly higher than on short-sleeved scrubs.[24] In a study employing a sampling protocol close to our own, uniforms (white coat, scrub, or other) demonstrated a high rate of colonization (45 CFU/25 cm^2), including 57% opportunistic human pathogen contamination by the end of the workday;[25] this was similar to our observed colonization rate at the end of an 8-hour day. Similarly, a study of microbial contamination in a military hospital in Jordan found a high level of contamination across all uniforms, although military uniforms were not distinctly classified.[21] The elevated bacterial burden of the personally owned uniforms in this study was predominantly attributed to the sleeve cuff and waist pocket, bearing the highest contamination. Two studies have similarly reported a higher rate of contamination at the sleeve cuff compared with other regions.[23,26] In contrast, the Jordanian military hospital study found that the abdominal and waist pocket areas of staff uniforms (indiscriminate) were most highly contaminated, whereas contamination was relatively low in the sleeve area.[21] Because of the in-house laundering services provided, that population was likely more comparable with the hospital-scrub wearers in our study, who observed the highest contamination at the abdomen as well. The sleeve cuff and waist pocket likely represent the 2 surfaces that the individual has the most hand/environmental contact with throughout the workday (reaching into the pocket to access/store items; the increased likelihood of sleeve cuffs on the dominant hand to touch patients during patient interactions, especially long-sleeved cuffs). A time-course analysis described distinct accumulation patterns according to uniform type. Staff donning personally owned uniforms harbored relatively high rates of bacterial contamination, even before the start of duty. This was not surprising, considering that similar studies have reported that home-laundered scrubs harbor an equal or greater number of bacteria than unwashed, worn scrubs.[27,28] This phenomenon appears to be unique to personally owned uniforms, as the maximum bacterial load detected on hospital-laundered scrubs on arrival was low. On the other hand, hospital-provided scrubs experienced an accumulation of bacteria within the first 4 hours of work, an observation that was only apparent on the sleeve cuffs of the personally owned uniforms. This

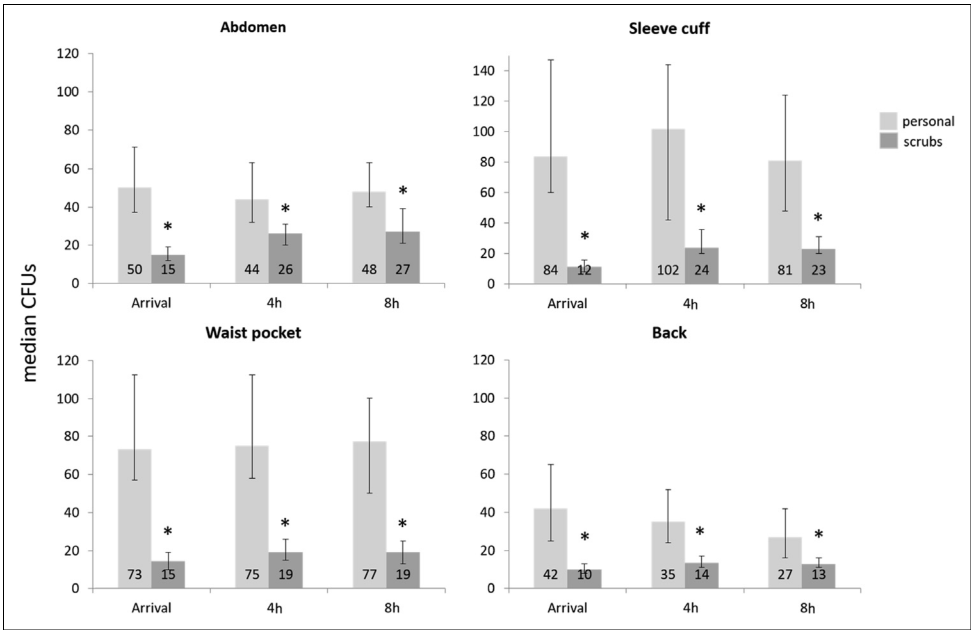

FIGURE 1

Colonization of nursing staff according to uniform type: "Personal" included any type of military service uniform or civilian personal scrubs. "Scrubs" included hospital-provided scrubs only. Bars display median. $^*P \leq 0.005$. Bar lines denote the lower and upper bounds of the 95% confidence interval. CFU, colony-forming units (per 25 cm^2) of 50 ED personnel.

supports the findings of Burden et al, who demonstrated that freshly laundered scrubs accumulate up to 50% of total daily bacteria within the first 3 hours of wear. Interestingly, neither uniform type displayed bacterial accumulation from 4 to 8 hours; rather, in some cases, bacteria were actually decreased. This is may be due to repeat sampling of the uniform site throughout the day.

Differences in bacterial colonization across uniform types may also bear some inherent factors. Since the report of seminal work describing distinct bacterial binding capacities of various cloth materials,[29] there has been interest in characterizing and developing textiles to mitigate microbial colonization in the health care setting. Although that goal is beyond the scope of this study, recent reports—such as the differential survivability of *Staphylococcus aureus* and *Escherichia coli* on cotton versus polyester[30]—may begin to offer insight on the innate factors that contribute to the health care uniform as a risk factor for HAIs.

Differences in bacterial load of diverse uniform types implicate uniform treatment (laundering, storage, carriage) and/or other human and behavioral characteristics as determinants of bacterial contamination. Owing to the demographic distinctions between the 2 subcategories in our study population (military and civilian nursing staff), hand-hygiene frequency and home- laundering frequency were evaluated as potential behavioral risk factors. Age has been reported as a factor of hand hygiene in various clinical settings.[31,32] In this study, however, an age-adjusted analysis revealed that age alone did not sufficiently account for significant differences in hand-hygiene frequency across subgroups in our ED population. This finding suggests that factors other than age may contribute to hand-hygiene adherence in a military health care setting, which falls in line with previously described work that found neither of education nor years of experience in the intensive-care unit were significantly related to uniform contamination in a military hospital.[21] Likewise, no correlation was found between the rate of pathogenic recovery and personnel's age or seniority in a study of nursing and physician staff in medical/surgical wards.[22]

A previous study has reported that frequency of attire change is a significant risk factor for rate of pathogenic contamination.[22] This is in line with reports of rapid and lasting accumulation of bacterial specimens on hospital textiles.[20,23] In addition, surveys have revealed that 26% of nurses do not wear freshly laundered uniforms daily.[16] In the current study, no significant differences were observed between the laundering frequency reported by either personnel subgroup, although a disproportionate number of military staff reported to work in uniforms worn 2 or more times without laundering (25% compared with 5% of civilians). Disparities in laundering frequency in this

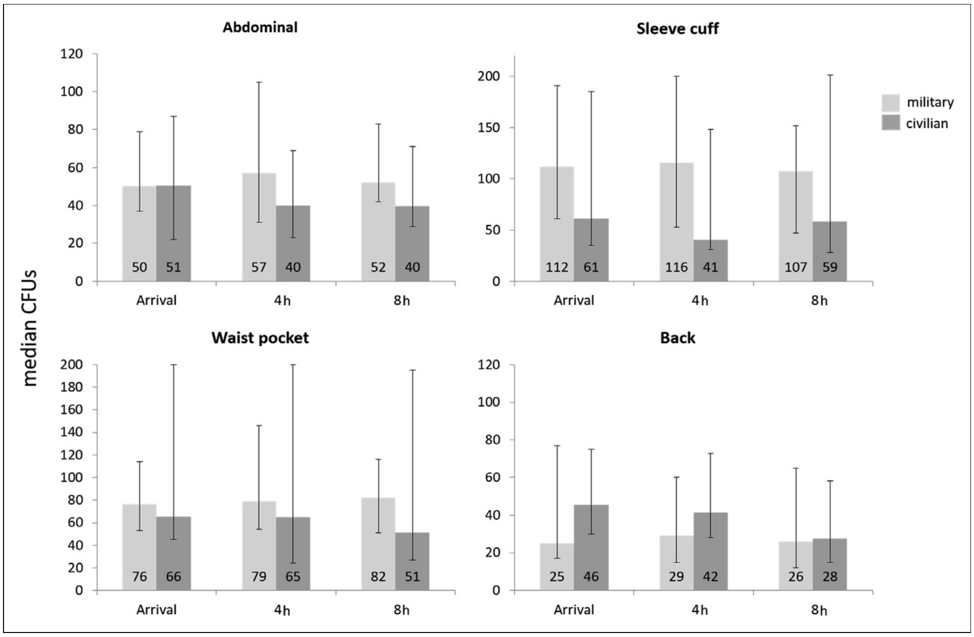

FIGURE 2

Colonization of military and civilian nursing staff: "Military" included either duty uniform or an approved modified duty uniform. "Civilian" included any hospital-approved civilian uniform. No hospital-provided scrubs were included in this analysis. Bars display median. CFU, colony forming units (per 25 cm^2) of 50 ED personnel. Bar lines denote the lower and upper bounds of the 95% confidence interval.

study may be related to increased cost and bulk of the active-duty uniform compared with cotton/polyester hospital scrubs typically worn by civilians. These differences, however, do not appear related to uniform colonization, as even civilian uniforms (worn only ≤1 times before laundering 95% of the time) contributed significantly to the susceptibility of contamination of personally owned uniforms. This implies that laundering patterns alone do not account for the increased bacterial burden of home-laundered uniforms. Some areas of interest include the potentially suboptimal nature of home laundering, which may be problematic in reducing microorganisms, owing to variations related to wash temperature, detergent, and drying time and temperature.[33] Other investigators have instead proposed that environmental exposures (eg, the home environment, *en route* to and from the hospital)[34,35] may explain differences in personally owned versus hospital-issued attire, and others have questioned the inherent propensity of fabrics to microbial colonization.[29]

Limitations

Some of the limitations of this study included the self-reported nature of behavioral data and the retrospective rather than observational design. However, the crossover design of the study helped to assess the reliability of the responses. In addition, to minimize disruption of staff and capture real-world conditions, a variety of personal uniform styles were sampled but not formally recorded (tucked, untucked tops, top length, sleeves rolled up), limiting our ability to identify uniform-related risk factors. Finally, the distribution of military and civilian personnel was not equal. However, this is the first study that characterized the uniform contamination of 2 subgroups in a military emergency department. Future work is required across multiple sites to validate the generalizability of our findings and more rigorously tackle the identification of contributing factors.

Implications for Emergency Nurses

Although direct evidence of transmission from uniforms to patients is lacking, the consensus across studies is that elevated bacterial loads increase the risk of HAIs. Given that freshly laundered attire has the capacity to rapidly accumulate and harbor pathogens until the next decontamination cycle (often at the discretion of personnel who, admittedly, don't launder daily), it is likely that policies conducive to daily laundering (eg, in-house laundry service) and increased hand hygiene may curb rates of hospital infection. Implications from this study would suggest that uniform policy (long sleeves, daily laundering) and targeted education (young military personnel) are just some opportunities for bolstering HAI interventions.

Conclusions

With the known elevated risk of blood and bodily-fluid contamination in the emergency department and the prevalence of conditions associated with decreased hand hygiene (crowding, high patient volumes), it is imperative to work toward organizational safeguards to protect personnel and vulnerable patients in the emergency department. The findings herein support the notion that personally maintained uniforms (of various styles) bode poorly in an assessment of bacterial accumulation from before duty hours to the end of the duty day. In addition, we identify factors that may have impact on susceptibility to colonization such as age, experience, and hand-hygiene frequency. Given the high levels of contamination, paired with the high volume of patients cared for within the emergency department, we recommend that nursing leadership require all staff to wear hospital-provided and hospital-laundered scrubs. This simple intervention has the potential to decrease health care-associated infections and improve patient outcomes. Although the costs associated with providing and laundering scrubs may seem high, these costs are typically lower than the costs associated with just 1 hospital-acquired infection.

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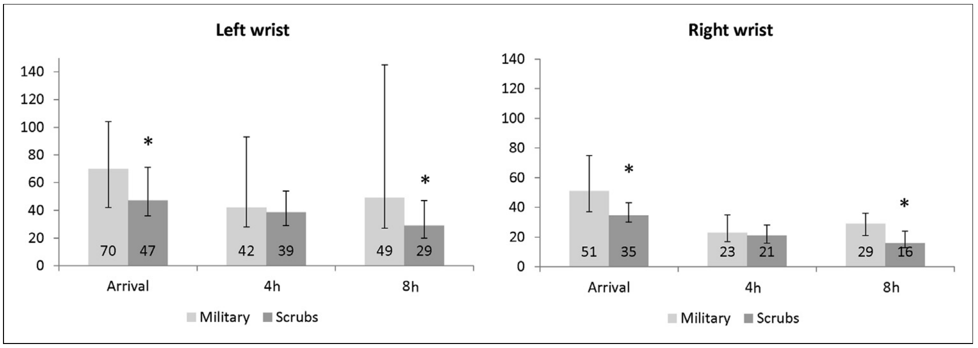
Supplementary Data



SUPPLEMENTARY FIGURE 1

Colonization of volar surfaces nursing staff according to uniform type: "Personal" included any type of military service uniform or civilian personal scrubs. "Scrubs" included hospital-provided scrubs only. Bars display median. *$P \leq 0.005$. Bar lines denote the lower and upper bounds of the 95% confidence interval. CFU, colony-forming units (per 25 cm^2) of 50 ED personnel.

SUPPLEMENTARY TABLE 1

Bacterial colonization on arrival by number of times uniform was worn prior to washing

Location	Number of previous uniform washings	CFU at time 0 on uniform						P value
		n	Mean	Std	Median	25th %ile	75th %ile	
(1) Waist	0	30	91	72	72	32	162	0.409
(1) Waist	>0	23	105	75	73	53	200	
(2) Cuff	0	30	98	73	73	41	185	0.414
(2) Cuff	>0	23	115	81	130	39	201	
(3) Abdomen	0	30	69	58	53	22	87	0.830
(3) Abdomen	>0	23	77	73	49	29	113	
(4) Back	0	30	62	57	46	17	77	0.700
(4) Back	>0	23	68	76	25	17	114	
(5) Left wrist	0	30	96	90	60	29	176	0.554
(5) Left wrist	>0	23	104	85	89	40	155	
(6) Right wrist	0	30	68	70	40	23	75	0.125
(6) Right wrist	>0	23	96	78	69	37	141	

ALL sampling was assessed from 0 hr (arrival) based on self-reported indication of number of times worn since uniform last worn, where 0 indicated uniform has been freshly laundered.
CFU, colony-forming units/25 cm^2.