ORIGINAL ARTICLE

Healthcare Personnel Attire and Devices as Fomites: A Systematic Review

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BACKGROUND. Transmission of pathogens within the hospital environment remains a hazard for hospitalized patients. Healthcare personnel clothing and devices carried by them may harbor pathogens and contribute to the risk of pathogen transmission.

OBJECTIVE. To examine bacterial contamination of healthcare personnel attire and commonly used devices.

METHODS. Systematic review.

RESULTS. Of 1,175 studies screened, 72 individual studies assessed contamination of a variety of items, including white coats, neckties, stethoscopes, and mobile electronic devices, with varied pathogens including *Staphylococcus aureus,* including methicillin-resistant *S. aureus*, gram-negative rods, and enterococci. Contamination rates varied significantly across studies and by device but in general ranged from 0 to 32% for methicillin-resistant *S. aureus* and gram-negative rods. *Enterococcus* was a less common contaminant. Few studies explicitly evaluated for the presence of *Clostridium difficile.* Sampling and microbiologic techniques varied significantly across studies. Four studies evaluated for possible connection between healthcare personnel contaminants and clinical isolates with no unequivocally direct link identified.

CONCLUSIONS. Further studies to explore the relationship between healthcare personnel attire and devices and clinical infection are needed.

Infect Control Hosp Epidemiol 2016;37:1367–1373

Transmission of pathogens within the hospital environment remains a hazard for hospitalized patients. Organisms such as *Staphylococcus aureus*, including methicillin-resistant *S. aureus* (MRSA), and vancomycin-resistant enterococci are associated with considerable morbidity, mortality, and healthcare costs and can be transmitted via environmental surfaces and inanimate objects. Healthcare personnel (HCP) themselves may represent a mobile surface for transmission via their contaminated apparel. Efforts to improve hand hygiene and reforms such as the United Kingdom's dress code policy of "bare below the elbow" have attempted to reduce this risk, but the professional wardrobe and numerous devices carried by care providers still represent potential risks. However, the magnitude of the risk is unclear. We performed a systematic review of the literature to evaluate the bacterial contamination of HCP attire and commonly used devices.

METHODS

We undertook a systematic search for studies that assessed the prevalence of pathogenic bacterial contamination of apparel and devices carried by HCP. MEDLINE, Cumulative Index to Nursing and Allied Health Literature, and Cochrane databases were searched. The following search terms were developed in MEDLINE and adapted for use in other databases: ("fomites"[MeSH] OR fomite* OR "Cross infection"[MeSH] OR nosocomial OR "Bacteria"[MeSH] OR "Bacterial Infections"[MeSH]) AND ("Equipment Contamination"[MeSH] OR "mobile phone" OR "mobile phones" OR "Cell Phones"[MeSH] OR "cellular phones" OR "cellular phone" OR Pager OR pagers OR Pens OR "writing utensil" OR "Personal Digital Assistant" OR "personal digital assistants" OR "Computers, Handheld"[MeSH] OR "smart device" OR "smart devices" OR ipad OR ipads OR purse OR purses OR handbag* OR badge OR badges OR lanyard* OR necktie* OR "white coat" OR "white coats" OR clothing OR uniforms OR attire OR stethoscope* OR otoscope* OR sphygmomanometer*) AND (health personnel OR physician OR physicians OR nurse OR nurses OR doctor OR doctors OR student OR students OR medical personnel). Related citations and bibliographies were also reviewed for additional studies of relevance. The search was last performed February 10, 2015. Studies were included if the prevalence of pathogenic bacteria, particularly *S. aureus* or gram-negative rods (GNR), was explicitly stated or able to be

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Received March 9, 2016; accepted July 7, 2016; electronically published September 9, 2016

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https://doi.org/10.1017/ice.2016.192 Published online by Cambridge University Press

extracted, the study was published in 1995 or later, and it was available in English. Studies of contamination of hands, gloves, isolation gowns, or environment were excluded. Studies of fungal or viral contamination were also excluded.

Extracted data included study location, population, item studied, and prevalence of contamination. Gram-negative rod contamination was reported on the basis of the individual authors' description of which isolates are pathogenic. Results from studies that included both inpatient and outpatient HCP were pooled into a single combined prevalence. In studies that compared personal equipment with environmental (dedicated) equipment, only the prevalence of contamination of personal equipment was included. Only contamination data from pretreatment or controls were used from studies that tested sanitation strategies. Prevalence of hand contamination was not included.

RESULTS

The systematic search yielded a total of 1,175 studies, 115 of which met criteria for full review. Of these, along with additional review of relevant citations and references, 72 unique studies were identified as meeting search criteria. These studies are described in Table 1.[1–76] Eighteen studies originated in the United States whereas the remainder were from Asia (24), Europe (19), Africa (5), other North American countries (5), and Australia (1). Various sampling techniques, microbiologic processes, and sensitivity tests were performed in the studies. Sampling techniques differed with the item studied, with 94% of phone studies using a sampling method using swabs whereas 60% of clothing studies used direct inoculation onto solid culture media. The most frequent microbiologic method was nonselective solid culture medium, such as blood agar, with or without additional selective media based on that study's pathogen of interest. Twenty-four studies analyzed contamination of stethoscopes, with MRSA contamination prevalence of 0–42% and GNR prevalence of 0–31%. Twenty-eight studies analyzed digital communication devices; 21 of these evaluated mobile phones explicitly. The range of MRSA contamination for phones was 0–20% and the range of GNR contamination for phones was 0–75%. One study[1] of tablets had MRSA contamination of 50%. Eight studies on white coats yielded rates of MRSA contamination of 0–16%, with one outlier[2] that was performed in the midst of an outbreak. GNR contamination of white coats ranged from 0 to 42%. Neckties had a reported MRSA contamination rate of 3%–32% and GNR contamination of 11%–23% in 5 studies. There was considerable variation in which areas of the white coats were sampled across the included studies.

Few studies explicitly evaluated for the presence of *Clostridium difficile*. One study[3] directed at *C. difficile* contamination of stethoscopes identified a contamination rate of 5%, whereas a second[4] identified no such contamination. Studies used a wide variety of classification schemes to report gram-negative rods, depending on the microbiologic methods used for isolation. Some provided species-level data whereas others reported only "GNR," "nonfermenting GNR," or "coliforms." *Enterococcus* contamination was inconsistently reported, and where it was included, vancomycin resistance was rare. The exception is a study[5] of nurses' uniforms with 39% contamination with vancomycin-resistant enterococci. Because of high variation in sampling technique and equipment, microbiologic methods, and reporting, no attempt was made to pool data from all studies or conduct a meta-analysis.

Three studies[5–7] were prospective. The remaining studies were cross-sectional. Four studies[2,8–10] attempted to correlate device or apparel contamination with clinical isolates.

DISCUSSION

We found that stethoscopes, digital devices, white coats, and neckties are commonly contaminated with bacterial pathogens including *S. aureus* (including MRSA) and GNRs, though there was high interfacility and interstudy variability. This may be due in part to the varied clinical settings included—inpatient vs outpatient vs emergency room and adult vs pediatric patient populations. However, even within a particular setting, variability persists. Possibilities include variable endemic rates of MRSA in the patient population and the hospital environment or local differences in hand hygiene or cleaning practices that may confound attire contamination. Another possibility is that there is no standardized approach regarding how to sample attire and devices, there may be differences in the ability of different types of swabs to pick up pathogens, and there may be variable efficiency of transfer of pathogens to and from different materials. For all these studies, sampling was not performed longitudinally, thus limiting the ability to evaluate persistent presence of pathogens. For most studies, the cleaning of devices or attire was not reported or taken into account at the time of sampling, which also may explain the wide ranges of prevalence of pathogens recovered from the items under study.

This review expands upon the findings of a prior systematic review[10] that focused only on contamination of digital devices and included 15 studies that sampled mobile phones, pagers, and personal data assistants for contamination with pathogens including MRSA and GNRs.

There is no evidence to date directly linking HCP-borne fomites with patient infection other than a report[11] of sternal wound infections linked to a nurse anesthetist. In that case, a cluster of 3 sternal wound infections due to *Gordonia bronchialis* triggered an epidemiologic survey that identified a nurse anesthetist involved in all 3 cases as the likely link. *Gordonia* was isolated from the nurse's axilla and hands as well as her scrubs and purse. Pulsed-field gel electrophoresis confirmed relatedness of these strains with clinical samples in each case. The pathogen was also identified in her home, and the authors suspect that home-laundering of scrubs may have led to the contamination. Our study does not attempt to correlate the presence of organisms on the objects sampled with

https://doi.org/10.1017/ice.2016.192 Published online by Cambridge University Press

TABLE 1. Systematic Review of Prior Studies on Healthcare Personnel Attire and Devices as Fomites, Sorted by Item, With Reported Prevalence of Contamination With Various Pathogens

Source	Population	Sample	*S. aureus*	MRSA	GNR	Notes
Stethoscopes						
Alleyne et al[3]	Inpatient physicians, UK	Stethoscopes	NR	NR	NR	5% (3/61) *C. difficile*
Bandi et al[13]	Inpatient pediatric HCP, UK	Stethoscopes	3% (1/40)	0% (0/40)	3% (1/40)	
Bernard et al[14]	Inpatient HCP, France	Stethoscopes	4% (15/355)	0% (1/355)	7% (25/355)	No MDR GNR
Burkharie et al[15]	Inpatient HCP, Saudi Arabia	Stethoscopes	0% (0/100)	0% (0/100)	9% (9/100)	
Campos-Murquia et al[16]	Inpatient HCP, Mexico	Stethoscopes	38% (43/112)	16% (18/112)	3% (3/112)	4% (4/112) *Enterococcus*
Cohen et al[17]	Outpatient pediatric physicians, Israel	Stethoscopes	55% (30/55)	7% (4/55)	18% (10/55)	
Fafliori et al[18]	ED physicians, Greece	Stethoscopes	7% (6/88)	2% (2/88)	3% (3/88)	
Fenelon et al[19]	Inpatient HCP, Ireland	Stethoscopes	NR	0% (0/44)	NR	
Jones et al[20]	ED HCP, USA	Stethoscopes	17% (25/150)	NR	NR	
Marinella et al[4]	Inpatient HCP, USA	Stethoscopes	38% (15/40)	NR	5% (2/40)	0% (0/40) *C. difficile* 5% (2/40) *Enterococcus*
Merlin et al[21]	EMS HCP, USA	Stethoscopes	NR	32% (16/50)	NR	
Nunez et al[22]	ED HCP, Spain	Stethoscopes	6% (7/122)	0% (0/122)	5% (6/122)	
Pandey et al[23]	Hospital physicians, USA	Stethoscopes	28% (22/80)	NR	18% (14/80)	
Panhotra et al[24]	Inpatient physicians, Saudi Arabia	Stethoscopes	48% (23/48)	4% (2/48)	15% (7/48)	8% (4/48) MDR *Pseudomonas*
Russell et al[25]	Inpatient HCP, USA	Stethoscopes	NR	0% (0/141)	NR	
Schroeder et al[26]	Inpatient and outpatient HCP, USA	Stethoscopes	5% (5/92)	3% (3/92)	18% (17/92)	
Sengupta, et al[27]	Inpatient pediatrics, India	Stethoscopes	28% (12/43)	28% (12/43)	21% (9/43) 5% (2/43) FQR	5% (2/42) *Enterococcus*
Smith et al[28]	Inpatient and outpatient HCP, USA	Stethoscopes	12% (24/200)	2% (4/200)	1% (2/200)	
Shiferaw et al[29]	Inpatient HCP, Ethiopia	Stethoscopes	45% (79/176)	12% (21/176)	31% (54/176)	
Sood et al[30]	Inpatient physicians, India	Stethoscopes	18% (19/106)	4% (4/106)	0% (0/106)	5% (5/106) *Enterococcus*
Tang et al[31]	ED staff, Canada	Stethoscopes	1% (1/100)	0% (0/100)	12% (12/100)	
Uneke et al[32]	HCP, Nigeria	Stethoscopes	42% (45/107)	42% (45/107)	25% (27/107), 17% (18/107) MDR	11% (12/107) *Enterococcus*
Whittington et al[33]	ICU HCP, UK	Stethoscopes	9% (2/22)	5% (1/22)	14% (3/22)	
Youngster et al[34]	Inpatient pediatric physicians, Israel	Stethoscopes	9% (4/43)	2% (1/43)	21% (9/43)	
Digital devices						
Akinyemi et al[35]	Hospital HCP, Nigeria	Mobile phones	16% (14/90)	0% (0/90)	9% (8/90)	4% (4/90) *Enterococcus*
Beer et al[36]	Inpatient HCP, Canada	Pagers	10% (10/100)	1% (1/100)	4% (4/100)	
Borer et al[37]	Inpatient HCP, Israel	Mobile phones	NR	NR	12% (15/124) *Acinetobacter*	
Braddy et al[38]	Inpatient HCP, USA	PDAs	2% (2/82)	0% (0/82)	2% (2/82)	1% (1/78) anaerobe
Brady et al[39]	Operating rooms, UK	Phones, pagers, PDAs	4% (3/78)	0% (0/78)	6% (5/78)	
Brady et al[40]	Inpatient HCP, UK	Mobile phones	8% (8/105)	2% (2/105)	5% (5/105)	1% (1/105) *Enterococcus*
Datta et al[41]	HCP, India	Mobile phones	36% (72/200)	13% (26/200)	0% (0/200)	0% (0/200) *Enterococcus*
Goldblatt et al[42]	Inpatient HCP, Israel and USA	Mobile phones	4% (17/400)	3% (10/400)	17% (67/400)	
Hassoun et al[43]	Inpatient HCP, USA	PDAs	11% (8/75)	8% (6/75)	0% (0/75)	1% (1/75) VRE
Hirsch et al[1]	Inpatient and outpatient pharmacy faculty, USA	Tablets	23% (7/30)	50% (15/30)	7% (2/30) *Pseudomonas*	3% (1/30) VRE
Jayalakshmi et al[44]	Clinical and non-clinical physicians, India	Mobile phones	23% (33/144)	3% (4/144)	6% (9/144)	1% (1/144) *Enterococcus*
Karabay et al[45]	Inpatient HCP, Turkey	Mobile phones	7% (9/122)	0% (0/122)	7% (8/122)	2% (2/122) VSE 0% VRE
Khivsara et al[9]	HCP, India	Mobile phones	40% (12/30)	10% (3/30)	NR	
Kilic et al[46]	Inpatient HCP, Pakistan	Mobile phones	8% (8/106)	NR	1% (1/106)	
Lee et al[47]	Inpatient HCP, South Korea	Mobile phones	25% (50/203)	4% (8/203)	4% (8/203)	0% (1/203) *Enterococcus)*
Namias et al[48]	Inpatient HCP, USA	Pagers	19% (7/36)	NR	22% (8/36)	6% (2/36) *Enterococcus*
Nwankwo et al[49]	Hospital HCP, Nigeria	Mobile phones	25% (14/56)	NR	59% (33/56)	High prevalence of antibiotic-resistance in GNR
Pandey et al[23]	Hospital physicians, USA	Mobile phones	8% (10/126)	NR	19% (24/126)	
Ramesh et al[50]	Inpatient HCP, Barbados	Mobile phones	0% (0/101)	0% (0/101)	15% (15/101)	
Sadat-Ali et al[51]	Inpatient and outpatient HCP, Saudi Arabia	Mobile phones	15% (44/288)	3% (8/288)	9% (26/288)	3% (10/288) *Enterococcus*
Saxena et al[52]	Physicians and nurses, India	Mobile phones	26% (26/100)	17% (17/100)	2% (2/100)	
Singh et al[53]	Inpatient and outpatient HCP, USA	Pagers	21% (21/100)	3% (3/100)	0% (0/100)	0% (0/100) *Enterococcus*
Smith et al[54]	Inpatient physicians, USA	Notebook computers	2% (1/60)	0% (0/60)	2% (1/60)	No *C. diff* recovered on culture of 17 devices; not tested for spores
Srikanth et al[55]	HCP, India	Mobile phones	12% (6/51)	4% (2/51)	18% (9/51)	
Tambekar et al[56]	Physicians, India	Mobile phones	24% (18/75)	20% (15/75)	75% (56/75)	

https://doi.org/10.1017/ice.2016.192 Published online by Cambridge University Press

Table 1. *Continued*

Source	Population	Sample	*S. aureus*	MRSA	GNR	Notes
Ulger et al[57]	OR and ICU HCP, Turkey	Mobile phones	25% (50/200)	13% (26/200)	8% (15/200) coliforms 10% (19/200) NFGN	4% (7/200) *Enterococcus*
Ustun et al[58]	Inpatient HCP, Turkey	Mobile phones	25% (45/183)	9% (17/183)	23% (42/183)	11% ESBL + GNR 1% (1/183) *Enterococcus*
Walia et al[59]	Inpatient, outpatient, and dental HCP, India	Mobile phones	18% (54/300)	11% (33/300)	13% (39/300)	
White coats						
Burden et al[6]	Inpatient physicians, USA	White coats	NR	16% (8/50)	NR	
Loh et al[60]	Medical students, UK	White coats	5% (5/100)	0% (0/100)	GNR isolated on 3%, not deemed pathogenic	
Munoz-Price et al[61]	ICU HCP, USA	White coats	32% (7/22)	0% (0/22)	32% (7/22)	5% (1/22) *Enterococcus*
Osawa et al[2]	Inpatient HCP, Japan	White coats	NR	79% (11/14); later 38% (9/24)		Performed during and after MRSA outbreak
Pandey et al[23]	Hospital physicians, USA	White coat	6% (8/130)	NR	NR	
Treakle et al[62]	Grand rounds attendees, USA	White coats	23% (34/149)	4% (6/149)	NR	0% VRE
Uneke et al[63]	Physicians, Nigeria	White coats	17% (18/103)	NR	26% (27/103)	
Wiener-Well et al[64]	Inpatient HCP, Israel	White coats	19% (10/52)	NR	42% (22/52)	*Acinetobacter* predominates GNRs. Rates reported per no. of cultures positive. Did not report contamination per coat.
Neckties						
Ditchburn[65]	Hospital physicians, UK	Neckties	20% (8/40)	3% (1/40)	NR	
Koh et al[66]	Inpatient physicians, Malaysia	Neckties	52% (26/50)	32% (16/50)	NR	
Lopez et al[67]	Physicians, UK	Neckties	32% (16/50)	NR	NR	
McGovern et al[68]	Physicians, Scotland	Neckties	11% (10/95)	8% (8/95)	11% (10/95)	0% VRE
Steinlechner et al[8]	Orthopedic surgeons, UK	Neckties	8% (2/26)	NR	23% (6/26)	
Pens						
Bhat et al[69]	ICU physicians and nurses, India	Pens	8% (6/75)	3% (2/75)	0% (0/75)	
Datz et al[70]	Inpatient physicians, Austria	Pens	2% (1/42)	0% (0/42)	7% (3/42)	
French et al[7]	Inpatient HCP, UK	Pens	NR	25% (9/36)	0% (0/8) MDR *Klebsiella*	17% (1/6) VRE Items sampled from wards with outbreaks with that pathogen.
Halton et al[71]	Inpatient HCP, USA	Pens	NR	NR	31% (4/13)	38% (5/13) *Staphylococcus*, not speciated
Pandey et al[23]	Hospital physicians, USA	Pens	14% (14/100)	NR	NR	
Wolfe et al[72]	ICU RTs, USA	Pens	0% (0/20)	0% (0/20)	0% (0/20)	
Other apparel						
Burden et al[6]	Inpatient physicians, USA	Short-sleeved uniforms	NR	20% (10/50)	NR	
Feldman et al[73]	Female physicians, USA	Purses	0% (0/13)	0% (0/13)	NR	69% (9/13) skin flora
Gaspard et al[74]	Long-term care facility HCP, France	Uniforms	NR	17% (43/256) waist 16% (42/256) pocket	NR	
Kotsanas et al[75]	Inpatient HCP, Australia	ID badge and lanyard	19% (11/59) badges, 25% (15/59) lanyards	5% (3/59) badges, 7% (4/59) lanyards	0% (0/59) badges, 14% (8/59) lanyards	2% (1/59) lanyards with *Enterococcus*
Munoz-Price et al[61]	ICU HCP, USA	Scrubs	11% (11/97)	4% (4/97)	11% (11/97)	3% (3/97) *Enterococcus*
Ota et al[76]	Inpatient HCP, Canada	ID badge	7% (8/118)	0% (0/118)	6% (7/118)	
Perry et al[5]	Nurses, UK	Uniforms	NR	14% (8/57)	NR	39% (22/57) VRE; 19% (11/57) *C. difficile*
Saxena et al[52]	Physicians and nurses, India	Rings	50% (50/100)	28% (28/100)	32% (32/100)	
Wiener-Well et al[64]	Inpatient HCP, Israel	White coats	22% (32/147)	5% (8/147)	78% (115/147)	60% *Acinetobacter*

note. Prevalence is reported as % of total items contaminated followed by number over *n* in parentheses; "*S. aureus*" indicates total contamination by methicillin-susceptible *Staphylococcus aureus* and methicillin-resistant *S. aureus* (MRSA), and "GNR" indicates pathogenic gram-negative rods as differentiated by the author. *C. difficile*, *Clostridium difficile*; ED, emergency department; EMS, emergency medical services; ESBL, extended-spectrum beta-lactamase; FQR, fluoroquinolone-resistant; HCP, healthcare personnel; ICU, intensive care unit; MDR, multidrug-resistant; NFGN, nonfermenting gram-negative rods; NR, not reported; PDA, personal data assistant; OR, operating room; RT, respiratory therapist; VRE, vancomycin-resistant *Enterococcus*; VSE, vancomycin-sensitive *Enterococcus*.

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transmission to patients or clinical infection, though some individual studies did attempt to make this link. Steinlechner et al[8] found 45% correspondence at the species level only between clinical isolates from surgical wound infections on inpatient orthopedic wards and isolates contaminating neckties from orthopedic surgeons. French et al[7] found that MRSA isolates from HCP pens had antimicrobial resistance patterns that corresponded to clinical isolates from an ongoing outbreak. Osawa et al[2] found that isolates of MRSA contaminating white coats during an outbreak on an inpatient ward were not genetically similar (on the basis of pulsed-field gel electrophoresis) to the outbreak strain whereas a later sampling in a non-outbreak setting did indicate genetic relatedness of clinical and HCP-derived strains. Khivsara et al[9] found that although antibiotic sensitivities were identical among MRSA isolated from HCP mobile phones and clinically derived specimens, molecular typing indicated that the strains were not related.

In 2014, the Society for Healthcare Epidemiology of America published recommendations[12] for healthcare facilities to address HCP attire, including the consideration of "bare below the elbows" policies, provision of white coat laundering services, and provision of hooks to remove white coats prior to patient contact. However, there remains a paucity of data linking attire or device contamination with patient infection, and the findings of this review call for research in the area of attire and mobile and other devices used by HCP.

Our findings have implications for clinicians and infection preventionists. Once hand hygiene practices have been optimized, attention to reducing reservoirs of organisms that may exist in clothing and devices is a reasonable next step in infection control. Possibilities include incorporation of attire policies consistent with Society for Healthcare Epidemiology of America recommendations, inclusion of stethoscope cleaning as part of hand hygiene practices, and implementation and enforcement of policies for cleaning shared patient items on a schedule agreed upon by unit staff.

Our study has limitations. The first limitation was the variability of methods in the individual studies. The included studies varied significantly by methods of sampling, including both site and method (eg, use of swab versus direct inoculation onto culture media). The microbiologic evaluation used also varied in many facets, including the extent to which pathogens were isolated and speciated and tested for antibiotic sensitivity.

Next steps for research in this area include the development of standardized methods and protocols that would enable more meaningful comparison between studies and institutions. A serial sampling strategy using longitudinal study design may yield important insights into the persistence of bacterial contamination. Given the paucity of data regarding *C. difficile* contamination relative to the importance of this pathogen in healthcare-associated infection in this era, further study specific to this pathogen is essential. Finally, while the use of new technology such as antimicrobial-impregnated fabrics or accessories has recently gained ground, methodologically rigorous study designs are needed to evaluate the impact of this novel technology on clinical outcomes rather than solely focusing on reducing contamination.

ACKNOWLEDGMENTS

Financial support. Department of Veterans Affairs, Veterans Health Administration, Health Services Research and Development Service Quality Enhancement Research Initiative (project no. PEC 15-248); and the Veterans Health Administration National Center for Patient Safety Center of Inquiry, United States Department of Veterans Affairs.

Potential conflicts of interest. All authors report no conflicts of interest relevant to this article.

Disclaimer: The views expressed in this article are those of the author(s) and do not necessarily represent the views of the Department of Veterans Affairs.

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