The Role of Health Personnel In Infection Control In Health Institutions

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Abstract

Healthcare-associated infections (HAIs) pose a significant challenge to patient and healthcare worker (HCW) safety, necessitating effective prevention measures. HCWs play a crucial role in infection control, as they are regularly exposed to blood and body fluids that can transmit pathogens. Contaminated textiles, including HCWs' clothing, contribute to the transmission of multidrug-resistant organisms (MDROs) within healthcare settings. Studies have shown that HCWs' uniforms and lab coats become contaminated through daily use, with pathogens such as methicillin-resistant Staphylococcus aureus (MRSA) and vancomycin-resistant enterococci (VRE) frequently detected. Proper use of personal protective equipment (PPE) and hand hygiene are critical strategies to mitigate the risk of pathogen transmission. However, compliance with these measures remains a persistent challenge. HCWs themselves can serve as reservoirs for MDROs, with nasal carriage rates of MRSA estimated between 6% and 15%. Laundering procedures, whether institutional or personal, also play a significant role in reducing contamination on healthcare textiles. The United States lags behind other nations in implementing healthcare facility-based laundering practices, with most HCWs washing their attire at home. Innovative textile technologies, such as fluid repellency and embedded antimicrobial agents, have shown promise in reducing microbial contamination on healthcare apparel. However, further research is needed to validate their effectiveness in clinical settings. Addressing the complex interplay of factors contributing to HAIs requires a comprehensive approach that includes proper PPE use, hand hygiene, effective laundering procedures, and the adoption of innovative textile technologies to minimize the risk of pathogen transmission between HCWs and patients.

Keywords: HCW, infection control, Healthcare-associated infections,HAIs

Introduction

Healthcare-associated infections (HAIs) represent a significant challenge to the safety of both patients and healthcare workers (HCWs), necessitating prioritization in healthcare systems and organizations for effective prevention measures (Al-Omari et al., 2020). The prevalence of HAIs is estimated to range between

5% and 15% among hospitalized patients, with a higher incidence of 9–37% reported in intensive care unit (ICU) admissions. In the United States (US), at any given time, approximately one in 25 hospitalized patients is affected by an HAI (Magill et al., 2014).

HAIs are associated with a reduction in quality of life and potentially decreased life expectancy for affected individuals. Additionally, they impose substantial long-term economic costs. For instance, the risk of acquiring an HAI following a needle-stick injury from an infected source patient is 0.3% for HIV, 3% for hepatitis C, and between 6–30% for hepatitis B. Globally, an estimated 3 million out of 35 million HCWs experience percutaneous exposure to bloodborne pathogens (BBPs) annually, with 2 million exposed to HBV, 0.9 million to HCV, and 0.17 million to HIV. The financial impact of HAIs in the US alone is approximately $6.5 billion annually. Beyond physical health consequences, HAIs have been linked to severe mental health issues such as anxiety, depression, adjustment disorder, panic attacks, and post-traumatic stress disorder (Wicker et al., 2014). While the global burden of HAIs is substantial and often underestimated, assessment methods exist but need to be simplified and made affordable, particularly in resource-limited settings. Preventive measures, such as hand hygiene, are often straightforward to implement. Thus, IPC should become a priority in national health programs, especially in low-resource countries. Encouragingly, up to 55–70% of HAIs are considered preventable. Preventative measures, including standard precautions like hand hygiene, use of gloves, gowns, eye protection, cough etiquette, and proper disposal of sharps, as well as isolation protocols to mitigate pathogen transmission risks, are widely recommended and implemented. Additional IPC strategies include infection-specific prevention, post-exposure prophylaxis for BBPs, and HCW immunizations to lower HAI rates.

The knowledge base of HCWs is critical for the effective implementation of IPC measures. A lack of awareness regarding IPC guidelines, preventive indications during routine care, and the risks of microorganism transmission to patients are substantial barriers to IPC compliance (Assefa et al., 2020). Inadequate knowledge about the efficacy, appropriateness, and application of IPC measures correlates with poor adherence (Aloush et al., 2018). To address these challenges, education and training are pivotal in enhancing IPC practices. However, studies have consistently shown gaps in HCWs' knowledge of IPC measures even after educational interventions. Awareness among HCWs should encompass aspects such as hand hygiene, proper use of personal protective equipment (PPE), immunizations for communicable disease prevention, infection transmission modes, infection assessment in patients, medical instrument sterilization, healthcare waste management, and policies on needle-stick and sharps safety. Most importantly, HCWs must adhere to IPC precautions and strategies to effectively reduce HAIs in healthcare settings.

Compliance with IPC protocols, including hand hygiene and PPE usage, varies significantly among HCWs. Factors influencing compliance include knowledge of infection risks and behavioral tendencies. Nevertheless, good knowledge does not always translate into effective IPC practices (Ogoina et al., 2015). For instance, despite the existence of established guidelines for HAI prevention, HCWs often exhibit suboptimal adherence to hand hygiene practices.

Addressing the issue of healthcare-associated infections (HAIs) and occupationally acquired infections involves managing a complex interplay of variables. A crucial factor is the role of healthcare workers (HCWs), including doctors, nurses, laboratory staff, and technical professionals, who are regularly exposed to blood and body fluids. These biological materials can transmit bacteria responsible for colonization or infection, including multidrug-resistant organisms (MDROs) such as meticillin-resistant Staphylococcus aureus (MRSA), Acinetobacter species, and Enterobacteriaceae (e.g., Escherichia coli, Klebsiella pneumoniae). Viruses such as noroviruses, respiratory viruses, and bloodborne pathogens (e.g., human immunodeficiency virus, hepatitis B and C viruses), which can persist on surfaces for extended periods, also pose a significant risk of transmission. In addition to acquiring microorganisms through occupational exposures, colonized HCWs themselves can serve as vectors, potentially transmitting pathogens to patients. Research indicates that 2–15% of HCWs may be colonized or infected with MRSA.

The evolving nature of healthcare delivery further complicates this issue. While HCWs in acute care settings, such as hospital operating rooms and emergency departments, anticipate exposure to blood and body fluids and use personal protective equipment (PPE) accordingly, advances in medical technology now enable invasive procedures to be conducted outside these environments. These non-traditional settings, including clinics and ambulatory or community settings, often present increased risks of accidental exposure to infectious agents due to limited access to PPE and reduced supervision, potentially leading to lower compliance with standard infection control measures. Additionally, HCWs traveling between healthcare facilities and public transportation while wearing work attire may inadvertently facilitate the transfer of microorganisms into and out of healthcare environments.

Globalization and the associated rise in international travel also exacerbate the risks associated with emerging infectious diseases. Over the years, novel infections have exposed deficiencies in public health systems worldwide. For example, during the early 2000s, gaps were identified in managing severe acute respiratory syndrome (SARS). Similarly, recent outbreaks of Ebola virus disease (EVD) and Middle East respiratory syndrome coronavirus (MERS) highlighted substantial deficiencies in global responses. In the

United States, these challenges were tragically illustrated by two HCWs contracting EVD from a patient who had traveled from West Africa to Dallas, Texas.

Viruses like Ebola are highly transmissible through body fluids, raising concerns about healthcare facilities' preparedness to manage such outbreaks. A survey of over 1,000 members of the Association for Professionals in Infection Control and Epidemiology (APIC) revealed that only 6% of respondents believed their hospitals were fully equipped to handle emerging threats like Ebola, while 20% reported that training programs for workers had not yet commenced.

Efforts to mitigate HAIs have primarily focused on cleaning and disinfecting non-porous, high-touch surfaces, yet the cleaning and decontamination of porous, soft materials and healthcare textiles (e.g., privacy curtains, linens, upholstery, and patient furniture) receive comparatively less attention. Textiles such as uniforms, scrub suits, and other apparel play a complex role in harboring and transmitting pathogens, further complicated by variations in laundering practices. Achieving optimal water temperatures, drying times, and dedicated process flows is challenging within healthcare facilities and nearly impossible in home laundering conditions. Although the US Centers for Disease Control and Prevention (CDC) and other agencies provide guidelines for laundering contaminated textiles, adherence to these recommendations remains difficult.

The contamination of healthcare textiles, including uniforms and other attire worn by HCWs, has been the subject of recent research and debate. Studies have explored the potential role of advanced barrier textiles with antimicrobial and fluid-repellent properties in mitigating occupationally acquired and healthcare-associated infections. Emerging evidence suggests that these novel fabrics may serve as an effective strategy to reduce cross-contamination risks. This paper offers a comprehensive review of current evidence on the risks posed by textiles in healthcare settings and evaluates the potential benefits of innovative materials in preventing the transmission of infectious agents between HCWs and patients.

Bioburden and Microbial Retention on Soft Surfaces

Experts assert that textiles such as curtains, upholstery, and apparel play a significant role in the acquisition and transmission of pathogens within healthcare settings. Healthcare workers' (HCWs') clothing serves as a vehicle for cross-contamination and the spread of multidrug-resistant organisms (MDROs)(G. Bearman et al., 2014). Contaminated soft surfaces contribute notably to both epidemic and endemic transmission of pathogens such as *Clostridium difficile*, vancomycin-resistant enterococci (VRE), methicillin-resistant *Staphylococcus aureus* (MRSA), *Acinetobacter baumannii*, *Pseudomonas aeruginosa*, and norovirus (Krueger et al., 2012).

Ohl et al. observed that 92% of hospital privacy curtains become contaminated with potentially pathogenic bacteria, including MRSA and VRE, within one week (Ohl et al., 2012). A review by Otter et al. highlighted that microorganisms shed by patients can contaminate surfaces in healthcare environments at levels sufficient for transmission. These pathogens can persist for extended periods despite cleaning efforts and are readily transferred to HCWs' hands. Otter et al. emphasized that the perception of negligible contributions from contaminated surfaces to nosocomial transmission is no longer tenable in light of emerging scientific evidence.

In contrast to environmental textiles such as curtains, HCWs' apparel is mobile within healthcare facilities and provides an optimal substrate for bacterial growth due to its contact with moisture and protein-rich debris. This allows clothing to acquire, retain, and disseminate epidemiologically significant pathogens like MRSA. Typically, HCWs wear the same clothing for an entire workday or longer, during which their attire comes into direct or indirect contact with coworkers, patients, and the general public.

At the end of a work shift, pathogens such as *C. difficile* and MRSA can be recovered from nurses' uniforms at counts exceeding 500 colony-forming units (cfu). One study revealed that 23% and 18% of lab coats were contaminated with methicillin-sensitive *S. aureus* (MSSA) and MRSA, respectively. Weiner-Well et al. reported that up to 60% of hospital staff uniforms were culture-positive for MDROs, based on samples taken from the sleeves, waists, and pockets of over 100 physicians and nurses. Healthcare-associated pathogens were identified on at least one site of 63% of these uniforms. Krueger et al. found that even laundered and unworn scrubs harbored normal skin flora, further complicating efforts to eliminate contamination.

In an observational study across six intensive care units, Morgan et al. determined that 21% of HCW–patient interactions resulted in contamination of HCWs' gloves or gowns, most frequently with multidrug-resistant *A. baumannii*. The study concluded that environmental contamination was the strongest predictor of MDRO transmission to HCWs' attire (Morgan et al., 2012). Other research, including studies by Treakle et al., confirmed that lab coats used in acute care settings become contaminated through daily use by HCWs. Similarly, Gaspard et al. found that HCWs' uniforms in long-term care facilities were heavily contaminated with MRSA.

A separate investigation examined the correlation between bacterial contamination on HCWs' hands, lab coats, and scrub suits. Among 103 HCWs, 86% of hands were contaminated, with *S. aureus* detected in 11%, *Acinetobacter* spp. in 6%, enterococci in 2%, and skin flora in 70% of cases. The presence of *Acinetobacter* spp. on HCWs' hands was associated with a higher likelihood of contamination of lab coats, but not scrubs.

Personal Protective Equipment (PPE) and Proper Hygiene

Protecting HCWs and other personnel responding to infectious disease outbreaks requires an effective occupational health program. According to the US Occupational Safety and Health Administration (OSHA), infection prevention programs should encompass measures for both patient and HCW safety, integrating these functions to optimize outcomes. Proper use of PPE, including timely donning of gloves and isolation gowns when interacting with colonized or infected patients, is a critical strategy to mitigate risk. Additionally, isolating patients in single rooms or cohorting them with others similarly infected are recognized as key practices to reduce cross-contamination and pathogen transmission.

Hand hygiene is another cornerstone of infection prevention. Washing hands with soap and water, using alcohol-based hand rubs, and ensuring proper glove use are fundamental measures to prevent MRSA transmission to patients and staff. HCWs' hands are a primary vector for healthcare-associated pathogens. Addressing the points of contact within this transmission network is vital for controlling the spread of MRSA and VRE.

Neely and Maley investigated the survival of 22 Gram-positive bacteria, including VRE, MSSA, and MRSA, on various hospital materials. They inoculated these materials—such as cotton clothing, terry towels, polyester scrub suits, privacy curtains, and polypropylene aprons—with 10^4 to 10^5 cfu of bacteria. All isolates were detectable for at least one day, with some persisting for over 90 days (Munoz-Price et al., 2012). These findings underscore the necessity for meticulous contact control procedures and thorough disinfection to limit bacterial transmission.

Even after proper hand hygiene and donning gloves, HCWs can inadvertently contaminate their gloved hands by touching themselves or objects within the environment, including high-touch surfaces, before interacting with patients. For instance, an observational study involving office workers found that they touched their eyes, lips, and nostrils at a frequency of 15.7 times per hour. Although HCWs may be more mindful of avoiding contact between their gloved hands and their bodies, Loveday et al. observed that gloved HCWs touched an average of three objects—such as clinical equipment or items like urine bottles and bedpans within the patient zone—before conducting healthcare procedures (Loveday et al., 2014).

Challenges in PPE Compliance

While adherence to hand hygiene protocols and PPE usage is fundamental to effective infection control programs, ensuring compliance remains a persistent challenge. Mitchell analyzed occupational exposure to blood across a cohort of more than 60 hospitals, noting that PPE use varied significantly, ranging from 25% in lower-risk areas to 75% in higher-risk areas. Furthermore, although well-established guidelines exist for preventing cross-contamination in high-risk settings like operating rooms and isolation wards, guidance for other hospital departments is limited. These areas often have more environmental touchpoints, increasing the risk of pathogen transmission. Consequently, relying solely on PPE and environmental disinfection is insufficient to prevent the spread of infectious microorganisms.

When caring for patients with laboratory-confirmed infections in isolation, HCWs are generally more diligent about handwashing and PPE use due to anticipated exposures. However, the lack of routine active screening for MDROs in many facilities leads to the treatment of unconfirmed cases, resulting in unanticipated and potentially unprotected exposures. Additionally, the shift towards outpatient and out-of-hospital care settings reduces the acute awareness of exposure risks, potentially increasing contamination and pathogen transmission.

HCWs as Infection Sources

HCWs themselves can serve as reservoirs for MDROs. Estimates place the nasal carriage rate of MRSA in HCWs between 6% and 8%, with some reports suggesting endemic rates as high as 15%. A study involving 135 surgeons and residents found that 1.5% carried MRSA, while 35.7% were positive for MSSA. Among residents, none were positive for MRSA, but 59% carried MSSA. In contrast, 2.7% of attending surgeons were MRSA-positive, and 23.3% carried MSSA.

Danzmann et al. reviewed 152 outbreaks, primarily in surgery, neonatology, and gynecology departments. The most common infections were surgical site infections, hepatitis B virus, and septicemia. Physicians were implicated in 59 outbreaks (41.5%), while nurses were associated with 56 outbreaks (39.4%), with transmission largely attributed to direct contact (Danzmann et al., 2013).

Laundering Procedures

HCWs may rely on institutional industrial laundering or personal laundering for their work attire. While industrial processes are generally effective in decontaminating garments, Fijan et al. highlighted that no procedure is entirely foolproof. Post-laundry handling activities, such as sorting, folding, and stacking, can reintroduce contaminants unless personnel maintain strict hygiene standards.

Fijan et al. identified key risks in the laundering process, including insufficient antimicrobial procedures and inadequate cleaning of laundry areas, which can facilitate microbial spread even in clean zones. Regular staff training on hygiene practices and thorough cleaning of laundry facilities are critical to minimize recontamination. In their study, rotavirus RNA was detected in hospital laundry rinse water and on laundered textiles, surfaces, and workers' hands, despite adherence to standard procedures.

Home laundering poses additional risks. Wright et al. investigated a cluster of *Gordonia bronchialis* sternal infections, ultimately tracing the source to a nurse anesthetist. Cultures from the nurse's scrubs, axilla, hands, and personal items, as well as from her roommate, confirmed contamination. Disposing of the home washing machine used for laundering uniforms effectively resolved the outbreak, highlighting the risks of home laundering (Wright et al., 2012). Another study found that 39% of nurses' uniforms laundered at home were contaminated with MDROs at the start of a work shift.

Even if laundering procedures effectively clean uniforms, bacterial recontamination begins shortly after donning. Home-laundered uniforms showed contamination levels rising from 39% at the start of a shift to 54% by the end of the day. Additionally, 100% of nurses' gowns became contaminated within one day of use, with 33% carrying *S. aureus*. Pockets and cuffs were identified as the most contaminated areas.

Burden et al. found that uniforms, nearly sterile before wear, accumulated 50% of their total bacterial load within the first three hours of use. Their study reported no significant differences in contamination between previously worn lab coats and freshly laundered uniforms or between the sleeve cuffs and pockets of either garment. Approximately 16% of lab coats and 20% of uniforms tested positive for MRSA, leading the researchers to suggest that reducing contamination on HCWs' clothing made from conventional fabrics would require changing attire every few hours.

Laundry Practices in the USA

The United States lags behind many other nations, particularly in Europe, due to the limited application of healthcare facility-based commercial or industrial laundering practices. Typically, only scrub suits used in operating rooms and isolation gowns are laundered in this manner. The US Centers for Disease Control and Prevention (CDC) recommends laundering contaminated linens at water temperatures of at least 160°F (70°C) with 50–150 ppm of chlorine bleach to effectively remove microorganisms from heavily contaminated fabrics. While healthcare laundry services may meet these guidelines, most HCWs wash their scrub suits, lab coats, and jackets at home. Domestic washing machines, however, generally do not exceed water temperatures of 110°F (45°C) due to child safety laws aimed at preventing burns. Furthermore, many scrub manufacturers discourage the use of bleach to preserve fabric color, a recommendation that conflicts with infection prevention practices in the healthcare field. Although high drying temperatures and the physical agitation during washing and drying cycles may reduce pathogen levels to a manageable threshold, this becomes problematic for those who opt for hand washing or air-drying garments for various reasons.

Textile Innovations: Fluid Repellency and Antimicrobial Properties

Equipping all hospital staff with gear comparable to nautical storm wear is impractical. Nonetheless, technical textiles featuring fluid repellency and embedded antimicrobial agents have been available for years as standalone technology options. Despite their potential benefits, healthcare facilities have been slow to adopt such innovations, likely due to insufficient recognition of their value in reducing infection risks and concerns over the higher costs associated with these enhanced materials.

Textile-based technologies that incorporate fluid repellency or active barrier antimicrobial properties may effectively mitigate cross-contamination risks by reducing microbial load on healthcare apparel. Bearman et al. demonstrated a 6-log reduction in *MRSA* contamination on scrub suits treated with a proprietary technology combining a breathable fluid barrier and non-leaching antimicrobial activity compared to untreated scrubs. Similarly, Schweizer et al. found that privacy curtains with a complex element compound incorporating antimicrobial properties took seven times longer to become contaminated than standard curtains. They concluded that such antimicrobial curtains could extend laundering intervals while potentially lowering pathogen transmission risks (Schweizer et al., 2012).

Research has shown that antimicrobial textiles alone may not suffice, and fluid repellency is critical for reducing the infectious dose in textile-based solutions (Boutin et al., 2014). Without hydrophobic properties, organic materials such as blood and bodily fluids may interfere with the antimicrobial agent's ability to inhibit or eradicate bacterial contamination.

Numerous studies have examined textiles with embedded antimicrobials, including silver and chitosan. Findings indicate that antimicrobials alone are insufficient to significantly reduce microbial growth, retention, and transmission. Mitchell corroborated this conclusion, noting that recent research has shown that antimicrobial-embedded textiles may not significantly reduce overall contamination (Mitchell, 2015). The application of antimicrobial textiles to environmental surfaces—such as privacy curtains, upholstery, or bedding—may differ in effectiveness compared to their use in apparel or uniforms, a distinction that warrants further investigation.

Other innovative textiles have shown promise in preventing microbial growth and contamination. For example, technical fabrics have reduced *MRSA* contamination levels on surfaces to nearly 0% within five minutes during splatter, spray, and contact challenge tests. Bearman et al. reported four- to seven-log reductions in *MRSA* on technical fabrics with fluid repellency and antimicrobial properties compared to traditional scrubs, both at the start and end of nurses' shifts (G. M. L. Bearman et al., 2012). These findings suggest that antimicrobial hydrophobic barriers are highly effective in reducing microbial bioburden on healthcare apparel. However, Bearman et al. did not observe significant reductions in microbes other than *MRSA*. They speculated that the baseline levels of Gram-negative bacteria in their hospital study may have been too low to detect significant differences. Designing studies to target epidemiologically relevant microbes is crucial to determining meaningful differences between textile types.

Regulatory Considerations

The US Food and Drug Administration (FDA) mandates only in-vitro testing for antimicrobial claims in pre-market notifications. Since clinical testing is not required, many antimicrobial products used in healthcare facilities are sold without clinical or hospital-setting validation. Before purchasing innovative antimicrobial or active barrier attire, healthcare facilities should assess whether the products are supported by data from clinically relevant settings, such as randomized or crossover studies conducted in healthcare environments. Additionally, facilities should evaluate the antimicrobial agent used and its mechanism of action, distinguishing between ionic association (leaching) and safer, non-leaching alternatives like covalent bonding.

Conclusion

The literature underscores that healthcare textiles, including uniforms and apparel, serve as vectors for the transmission of microorganisms that cause infections and illnesses among HCWs, patients, and the broader community. Although there is an expanding body of published studies addressing this topic, its impact remains underestimated due to the limited investigation of textiles as point sources during outbreaks or individual cases of infection.

Numerous papers either begin or conclude by highlighting the paucity of data in the literature concerning technical textiles or apparel innovations. Consequently, healthcare facilities, hospitals, outpatient clinics, and academic institutions are encouraged to adopt and systematically evaluate newly available control measures, sharing their findings and outcomes through credible, peer-reviewed publications.

PPE plays an established role in safeguarding HCWs when there is a recognized risk of exposure to blood, body fluids, or contact-transmissible pathogens. However, exploring innovations in everyday apparel and frequently used textiles may further reduce endemic transmission risks to patients. Current evidence suggests that antimicrobial-embedded textiles alone are insufficient. Manufacturers are capable of engineering or designing technical textiles to minimize the acquisition, retention, and transmission of infectious microorganisms from blood, bodily fluids, and environmental sources, while also addressing higher levels of soil or bioburden. Achieving optimal product design, safety, and effectiveness necessitates collaborative partnerships among healthcare institutions, research organizations, academic settings, public agencies, and manufacturers. Bridging the gap between current and future healthcare apparel could benefit all stakeholders.

Historically, advances in apparel have been made in industries with fire hazards through the development of fire-retardant and fire-resistant textiles. Similarly, it is highly plausible that novel fabrics capable of providing protection against microorganisms will become standard in healthcare settings in the years ahead.

Finally, a statement made nearly a decade ago by Jagger of the International Healthcare Worker Safety Center remains as relevant today as it was then and can be extended to include the risks posed by a broader range of pathogens:

“The basic measures for protecting HCWs from the life-threatening risk of bloodborne pathogen infection should be viewed everywhere as essential and included in the national health priorities of all nations. The resources for this task are unlikely to be forthcoming unless we re-assess the value we place on HCWs. They are not merely a service commodity; they are an invaluable asset to their countries and to the world community. Without them there would be no health care. All of us benefit from protecting their lives and health” .

References

Al-Omari, A., Al Mutair, A., Alhumaid, S., Salih, S., Alanazi, A., Albarsan, H., Abourayan, M., & Al Subaie, M. (2020). The impact of antimicrobial stewardship program implementation at four tertiary private hospitals: Results of a five-years pre-post analysis. *Antimicrobial Resistance & Infection Control*, *9*(1), 95. https://doi.org/10.1186/s13756-020-00751-4

Aloush, S. M., Al-Sayaghi, K., Tubaishat, A., Dolansky, M., Abdelkader, F. A., Suliman, M., Al Bashtawy, M., Alzaidi, A., Twalbeh, L., Sumaqa, Y. A., & Halabi, M. (2018). Compliance of Middle Eastern hospitals with the central line associated bloodstream infection prevention guidelines. *Applied Nursing Research: ANR*, *43*, 56–60. https://doi.org/10.1016/j.apnr.2018.06.018

Assefa, J., Alen, G. D., & Adane, S. (2020). Infection prevention knowledge, practice, and its associated factors among healthcare providers in primary healthcare unit of Wogdie District, Northeast Ethiopia, 2019: A cross-sectional study. *Antimicrobial Resistance & Infection Control*, *9*(1), 136. https://doi.org/10.1186/s13756-020-00802-w

Bearman, G., Bryant, K., Leekha, S., Mayer, J., Munoz-Price, L. S., Murthy, R., Palmore, T., Rupp, M. E., & White, J. (2014). Healthcare Personnel Attire in Non-Operating-Room Settings. *Infection Control & Hospital Epidemiology*, *35*(2), 107–121. https://doi.org/10.1086/675066

Bearman, G. M. L., Rosato, A., Elam, K., Sanogo, K., Stevens, M. P., Sessler, C. N., & Wenzel, R. P. (2012). A Crossover Trial of Antimicrobial Scrubs to Reduce Methicillin-Resistant Staphylococcus aureus Burden on

Healthcare Worker Apparel. *Infection Control & Hospital Epidemiology*, *33*(3), 268–275. https://doi.org/10.1086/664045

Boutin, M. A., Thom, K. A., Zhan, M., & Johnson, J. K. (2014). A Randomized Crossover Trial to Decrease Bacterial Contamination on Hospital Scrubs. *Infection Control & Hospital Epidemiology*, *35*(11), 1411–1413. https://doi.org/10.1086/678426

Danzmann, L., Gastmeier, P., Schwab, F., & Vonberg, R.-P. (2013). Health care workers causing large nosocomial outbreaks: A systematic review. *BMC Infectious Diseases*, *13*(1), 98. https://doi.org/10.1186/1471-2334-13-98

Krueger, C. A., Murray, C. K., Mende, K., Guymon, C. H., & Gerlinger, T. L. (2012). The bacterial contamination of surgical scrubs. *American Journal of Orthopedics (Belle Mead, N.J.)*, *41*(5), E69-73.

Loveday, H. P., Lynam, S., Singleton, J., & Wilson, J. (2014). Clinical glove use: Healthcare workers' actions and perceptions. *Journal of Hospital Infection*, *86*(2), 110–116. https://doi.org/10.1016/j.jhin.2013.11.003

Magill, S. S., Edwards, J. R., Bamberg, W., Beldavs, Z. G., Dumyati, G., Kainer, M. A., Lynfield, R., Maloney, M., McAllister-Hollod, L., Nadle, J., Ray, S. M., Thompson, D. L., Wilson, L. E., Fridkin, S. K., & Emerging Infections Program Healthcare-Associated Infections and Antimicrobial Use Prevalence Survey Team. (2014). Multistate point-prevalence survey of health care-associated infections. *The New England Journal of Medicine*, *370*(13), 1198–1208. https://doi.org/10.1056/NEJMoa1306801

Mitchell, A. H. (2015). Making the Case for Textiles with a Dual Mechanism of Action. *Infection Control & Hospital Epidemiology*, *36*(4), 486–487. https://doi.org/10.1017/ice.2014.92

Morgan, D. J., Rogawski, E., Thom, K. A., Johnson, J. K., Perencevich, E. N., Shardell, M., Leekha, S., & Harris, A. D. (2012). Transfer of multidrug-resistant bacteria to healthcare workers' gloves and gowns after patient contact increases with environmental contamination*. *Critical Care Medicine*, *40*(4), 1045. https://doi.org/10.1097/CCM.0b013e31823bc7c8

Munoz-Price, L. S., Arheart, K. L., Mills, J. P., Cleary, T., DePascale, D., Jimenez, A., Fajardo-Aquino, Y., Coro, G., Birnbach, D. J., & Lubarsky, D. A. (2012). Associations between bacterial contamination of health care workers' hands and contamination of white coats and scrubs. *American Journal of Infection Control*, *40*(9), e245–e248. https://doi.org/10.1016/j.ajic.2012.03.032

Ogoina, D., Pondei, K., Adetunji, B., Chima, G., Isichei, C., & Gidado, S. (2015). Knowledge, attitude and practice of standard precautions of infection control by hospital workers in two tertiary hospitals in Nigeria. *Journal of Infection Prevention*, *16*(1), 16–22. https://doi.org/10.1177/1757177414558957

Ohl, M., Schweizer, M., Graham, M., Heilmann, K., Boyken, L., & Diekema, D. (2012). Hospital privacy curtains are frequently and rapidly contaminated with potentially pathogenic bacteria. *American Journal of Infection Control*, *40*(10), 904–906. https://doi.org/10.1016/j.ajic.2011.12.017

Schweizer, M., Graham, M., Ohl, M., Heilmann, K., Boyken, L., & Diekema, D. (2012). Novel Hospital Curtains with Antimicrobial Properties: A Randomized, Controlled Trial. *Infection Control & Hospital Epidemiology*, *33*(11), 1081–1085. https://doi.org/10.1086/668022

Wicker, S., Stirn, A. V., Rabenau, H. F., von Gierke, L., Wutzler, S., & Stephan, C. (2014). Needlestick injuries: Causes, preventability and psychological impact. *Infection*, *42*(3), 549–552. https://doi.org/10.1007/s15010-014-0598-0

Wright, S. N., Gerry, J. S., Busowski, M. T., Klochko, A. Y., McNulty, S. G., Brown, S. A., Sieger, B. E., Michaels, P. K., & Wallace, M. R. (2012). Gordonia bronchialis Sternal Wound Infection in 3 Patients following Open Heart Surgery: Intraoperative Transmission from a Healthcare Worker. *Infection Control & Hospital Epidemiology*, *33*(12), 1238–1241. https://doi.org/10.1086/668441