5-4-2022

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American Journal of Infection Control 000 (2022) 1–15

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

Major Article

Recommendations for change in infection prevention programs and practice

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Keywords:
Infection prevention and control programs
Surveillance
Environment of care
Decolonization
Healthcare-associated infections
Antibiotic-resistant organisms
Emerging pathogens

A B S T R A C T

Fifty years of evolution in infection prevention and control programs have involved significant accomplishments related to clinical practices, methodologies, and technology. However, regulatory mandates, and resource and research limitations, coupled with emerging infection threats such as the COVID-19 pandemic, present considerable challenges for infection preventionists. This article provides guidance and recommendations in 14 key areas. These interventions should be considered for implementation by United States health care facilities in the near future.

2022 marks the 50th anniversary of the founding of the Association for Professionals in Infection Control and Epidemiology (APIC), an organization devoted to advancing the science and practice of infection prevention and control. Over these years, the position and department title has transitioned from “Infection Control” to “Infection Prevention and Control” in order to better reflect the fundamental goals. In addition, infection prevention (IP) programs in health care facilities nation-wide have enhanced the culture of safety through modifications in each organization’s systems of care by assessing efficacy, and revising, standardizing, and monitoring clinical and ancillary practices. Coordinated efforts at reducing health care-associated infections (HAIs) have been determined to be effective to vary degrees when IP programs are provided with adequate resources and supported by the implementation of evidence-based strategies.[1,2] Multifaceted HAI prevention programs have been proven to be cost-effective, a finding of vital importance in the present landscape of health care reimbursement and therefore, in the overall financial health of the institution.[3,4] IP efforts have been facilitated by the application of such fundamental tools as core components,[5] competency models,[6] and implementation science[7] which assist infection preventionists (IPs) to bridge gaps

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Conflicts of interest: None to report.

https://doi.org/10.1016/j.ajic.2022.04.007
0196-6553/

between organizational barriers to change and successful outcomes.

Although marked with many significant triumphs over our first 50 years, IP challenges posed in present-day health care settings have created new questions and compelled IPs to re-assess our approaches to reduce infection risk and to control known and emerging pathogens. This article, authored by experienced IPs, epidemiologists, and other content experts, provides guidance for addressing critical issues currently affecting IP programs with an emphasis on the implementation of innovative, cost-effective, and evidence-based interventions, engaging health care leaders and experts in clinical care in proven prevention measures, holding staff accountable, and adopting high-reliability principles.

KEY IP CHALLENGES AND RECOMMENDATIONS FOR CHANGE:

IP Program Standardization

The creation of reliable design of processes is a methodology that has been used in businesses including the airline industry and health care to produce better outcomes by reducing defects such as the ineffective use of time. According to the science of reliable design, the establishment of such a template IP program would support replication of best practices, avoidance of errors, and would ultimately optimize processes.[8-10] The Infrastructure Report and the APIC IP Competency Model provide a starting point for the creation of this reliable design, by recommending standard priority areas of focus for IP professionals.[11,12] However, neither provides scientific evidence to recommend a standard percentage of time dedicated to each priority area, in addition to recommendations regarding other critical components of an IP program including staffing levels, (interns, surveillance assistance, IP lead, manager, director, etc.) reporting structure and physician participation.

Currently, how IPs allocate their time each day varies widely among health care facilities and across the continuum of care, driven in part by regulations, the priorities of the IPs' manager, and by the strengths and interests of the IP professional. The 2015 APIC Mega Report provides a listing of the average percent of time spent on key IP focus areas but does not address the variability from hospital to hospital.[11]

Although reporting structure is key to the success of an IP program, there is currently wide variation regarding hierarchical reporting with some programs reporting to Quality departments, some to Nursing, some to patient safety, and a few directly to the C Suite or executive level.[13] Physician partnership in IP programs have been proven to be important for optimal outcomes, although at present there is no national certification process to support standardization of the role and training of the physician in IP programs.[14] And finally, IP department staffing is also lacking standardization. A recent peer-reviewed study concludes that the actual IP staffing level in US hospitals is anywhere between 31% and 66% above the current outdated benchmark of 0.5-1.0 IP per 100 occupied beds.[15] Research is needed in order to define the ideal for each of these essential program components, which would together provide a reliable design for a best practice IP program.

Also, the pandemic has shown us the importance and need for more robust IP in different care settings, for example, nursing homes, behavioral health centers, and long-term acute care (LTAC) centers. In addition, ambulatory and outpatient IP is an ever important area requiring additional IP presence that is also lacking and frequently on the lowest priority for the average IP assigned to the acute care setting. The best practice IP program must, therefore, address IP across the continuum of care, spanning from outpatient to acute, to alternative care settings.[16]

Surveillance

The National Healthcare Safety Network (NHSN) has served as the backbone of HAI surveillance with nearly 25,000 participating medical facilities.[17] Standardized surveillance definitions and their application became all-encompassing to a point that for many IPs it defined their profession. As years passed, surveillance definitions became complicated, inconsistent from year to year, and subject to interpretative bias. In 2015, a systematic review was published highlighting this variability with 1 significant-conclusion, surveillance definitions need to be revised.[18] NHSN definitions have been scrutinized over the years due to criteria that are perceived to not better reflect the clinical representation. Therefore, new partnerships between NHSN and the IP community, and other stakeholders will be important to evolve to future measures that are easily captured and more reflective of the quality of clinical care and processes. In addition, surveillance metrics became tied to public reporting measures, federal incentives, and penalties, as well as private insurer quality metrics that drove reimbursement. This phenomenon has increased pressure on IP programs to ensure prospective surveillance that is rooted in accuracy and speed.

Given the scope and complexity of surveillance activities, it has been estimated that 45% of IP time is consumed by this activity. According to Hebden, most IP programs have not addressed this unsustainable time requirement by adopting an electronic solution which is also known as a data mining system. This has a significant impact on performance improvement activities and other IP program-related functions, particularly in a low-resourced department. Surveillance accuracy was also determined to be poor and according to a 2017 study respondents to case studies over 6 years showed 62.5% accuracy with a range of 16%-87%.[19] Manual surveillance has proven itself to have inaccuracies and unsustainable time commitment which negatively impact IP programs exponentially.

Automated surveillance software has recently been addressing a need for accuracy and time efficiency. Multiple vendors are now competing to provide medical facilities with agile and user-friendly tools to achieve surveillance goals. However, caution must be taken when determining the appropriate surveillance system for IP programs. A systematic review published in 2020, concluded that estimated benefits of automated surveillance were still premature and that less than 20% of the studies were able to cite any efficiencies gained.[20] These findings are directly tied to multiple factors that IP must consider. Many systems offer a wide array of solutions and integration within facility electronic health records (EHR). However, the ability to detect specific EHR information will render automated surveillance a success or a failure.[21] The main factors that IP must consider include implementation, maintenance, and training costs, prerequisites for integrating communication between the surveillance system and the multitude of modules in an EHR, reporting and install capabilities, malleability of the software to tailor its focus and streamline data points and resourcing of ongoing maintenance.[22] It is critical for current and future IPs to have a robust knowledge of electronic solutions and integrate the right platform taking these variables into consideration.

HAND HYGIENE

Hand hygiene (HH) compliance among health care providers (HCP) continues to be a significant challenge for many organizations. HH noncompliance occurring in health care institutions are multifactorial with the main causes reported in a Joint Commission assisted 8-hospital study including ineffective placement of dispensers or sinks, HH data compliance data not collected or reported accurately, lack of coaching, an issue not included as part of safety culture, ineffective education, and HCP distractions.[23] IP programs struggle to

meet the demands HH noncompliance places on their organization through HH is undisputed as the number 1 method for reducing HAIs.

Programs designed to improve HH compliance involve leadership support and extensive system integration. A strategy advocated by the World Health Organization (WHO) is comprised of 5 elements which are all touted as essential and complementary: System Change (Build it), Education (Teach it), Monitoring and Feedback (Check it), Communication (Sell it), and Culture Change (Live it).[24]

Within these elements are issues that require further research. For example, although direct observation is the gold monitoring standard there remains a lack of standardization in the methodology, with direct or overt HH observations rates reported as much higher than indirect or covert observations.[25] One study that determined baseline HH average compliance rates of 47.5% across 8 hospitals reported that observers were initially unable to determine the causes of noncompliance simply by visually observing practice due to behavioral influences.[23]

Observation methods have their own inherent problems as evidenced by the well-documented Hawthorne effect. Education of the observer can vary however a standardized method of "train-the-trainer" has been demonstrated as an effective and efficient method for sharing knowledge. This method along with simulation was used in a multicountry 3-day course based on the WHO multimodal HH improvement strategy resulting in a statistically significant improvement in participant knowledge.[26] Furthermore, sustainability was achieved after evaluation 2 years later. Though proven effective, simulation in a lab environment is not always available and not widely used. Regardless of the improvement methodology used or the strength of individual components, multimodal strategies have proven to be the most successful.[27-29]

Recent interest has been given to supplemental methods for monitoring HH compliance. To address this issue, an automated hand hygiene surveillance system (AHHSS) has been developed. A recent study examining the impact of an AHHSS installed on 4 patient units in 1 hospital, reported unit-specific baseline quarterly averages of 66%-95% by direct observation with postintervention of 77%-90%.[30] It is important to note improvements in HH compliance rates were not observed on all units in this study using the AHHSS, while those units that did increase compliance rates improved after implementation of additional interventions, including the Toyota Kata performance improvement methodology. The methodology attempts to change behavior using a defined step-by-step process. Reductions in non-*Clostridioides difficile* HAIs occurred but were not statistically significant.

A recent review of 73 studies using AHHSS indicated that such systems "…face issues of accuracy, data integration, privacy and confidentiality, usability, and associated costs as well as infrastructure improvements." [31] Such limitations, including lack of standardization, reduce accuracy, thus circumventing the intended process. Data validation and reporting can be problematic when the system isn't supported internally by executives, therefore, placing an additional burden on IP responsibilities. Improvements in automated systems include integration with cloud technology, therefore, decreasing the need for facility information technology (IT) department support.[32]

Additional influences in monitoring are in part due to regulatory and nonprofit groups. In 2019, The Leapfrog Group, a nonprofit consumer "watchdog" organization, added a new HH standard to their hospital and ambulatory surgery center (ASC) surveys.[33] Adherence to the standard by participating hospitals is measured by compliance in 4 of 5 domains, which include training and education, infrastructure, culture, and adherence to a defined number of observations which may be assisted by the use of an electronic monitoring system. The consideration for implementation of this monitoring methodology should take into account various issues including the impact on an organization's finances, training capabilities, and staffing levels as the program requires meeting specific standards such as a minimum number of observations covering all units, shifts, and days of the week, feedback on HH compliance data to individuals who have contact with patients or with items to be used by patients while conducting a direct overview of observers to ensure that the process is uniform and consistent. Hospitals that elect not to participate in Leapfrog, should realize that publicly reported information will instead be used in their published reports.

In conclusion, recommendations to address future HH challenges include the need to conduct further studies addressing the influence of human behavior and system culture on HH practices, new approaches in training and education, investigation of the most effective monitoring strategies, as well as determining the best processes for enhancing communication of monitoring results, and the linking of said results to health care personnel performance reviews.

ENVIRONMENTAL CONTAMINATION

The sources and routes of pathogen transmission in health care settings have been well researched.[34] The most significant source is the patient who is colonized or infected and may shed organisms from body sites, bedding, gowns, and contaminate nearby environmental surfaces and portable equipment used in their care. The frequency of pathogen transfer from patients and their environment to HCP hands, gloves, and gowns have been demonstrated to be 33%, 30%, and 10%, respectively. Also concerning is the finding that the hands of HCPs are just as likely to be contaminated by touching an environmental surface as by direct contact with a patient.[35]

In acute care settings, the patient environment is "…defined as the area inside the curtain, including equipment, medical devices, furniture, telephone, personal belongings, and the bathroom."[36] Multiple studies indicate that the patient environment plays an important role in the transmission of many pathogens of concern in health care including methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant *Enterococcus* (VRE), gram-negative organisms such as *Pseudomonas aeruginosa*, and *C difficile*.[37-39] These and many other pathogens have been known to persist on environmental surfaces from hours to days, and in the case of spore-forming organisms, months.[40] Studies have demonstrated that when a patient is colonized or infected with organisms including MRSA, VRE, and *Acinetobacter*, the risk of acquisition of these organisms by a newly admitted patient to the same room is increased.[41] In a large study of 10,289 HAIs occurring over 7 years in 4 hospitals,[42] the risk of acquiring an HAI was nearly 6-fold when a prior bed occupant was colonized or infected with a pathogen.

Evidence suggests that adequate cleaning of patient rooms is often insufficient. In 2 large studies[43,44] (23 and 16 hospitals, respectively) researchers used a fluorescent solution applied on room surfaces located in a patient's immediate environment and a hand-held ultraviolet light device to assess the adequacy of cleaning. The studies concluded that only 49% and 57.1% of the surfaces were adequately cleaned.

Several important points should be considered when determining how best to improve patient room cleaning and disinfection in a health care facility. First, studies examining the efficacy of education of environmental services (EVS) staff, key patient safety persons, have demonstrated minimal improvement, with 5%-30% of surfaces remaining potentially contaminated.[45] Secondly, the effect of improved environmental cleaning and disinfection on patient *acquisition* of pathogens, appears to be variable. One review of the literature reported a reduction in the rates of MRSA, VRE, and *C difficile* infection (CDI) from 0% to 49% after improvement in cleaning practices, with 1 study demonstrating an 83% reduction in VRE bacteremia.[34] Thirdly, monitoring of cleaning practices, which include

traditional visual inspection, microbiological sampling, and nonmicrobiological testing such as fluorescent markers used as surrogates for residual contamination and quantification of adenosine triphosphate (ATP) levels to determine persistence of organic material, lack universal acceptable standard levels of residual contamination.[46] Fourth, concentration solely on cleaning "high-touch" surfaces often prevents thorough and complete room decontamination.[47]

Hospitals are investigating automated supplemental environmental disinfection processes with increasing frequency in response to failures associated with human factors such as inadequate or overlooked manual cleaning of objects, lack of proper supervision and monitoring, lack of resources, and low levels of hand hygiene.

Automated supplemental disinfection technology can currently be categorized as mobile devices that are used for terminal room disinfection and technologies that provide continuous surface disinfection. The principle mobile technologies represented in peer-reviewed studies incorporate the automated emission of chemical vapors, aerosols or ultraviolet (UV), and hand-operated electrostatic sprayers. The most comprehensive clinical trial to assess a UV-C "no-touch" technology is the Benefits of Enhanced Terminal Room Disinfection (BETR-D) study, the results of which were published in 2017.[48] This multihospital study concluded that the addition of a UV-C device to the standard manual process of terminal cleaning and disinfection decreased patient acquisition of a target organism by approximately 10% to 30%, suggesting that the environment is responsible for a significant portion of antibiotic-resistant organism (ARO) acquisition.[48] Factors such as organic load, pathogen type, intensity, surface types, distance of the surface from the UV device, placement of the device in the room, exposure time, room size and configuration, and air movements, all contribute to the relative efficacy.[49]

Studies using hydrogen peroxide (HP) decontaminating systems report 86%-100% reduction in MRSA, VRE, and multidrug-resistant gram-negative bacteria on contaminated surfaces in hospital rooms,[50,51] with reported reductions in 10 published studies,[52] although an analysis of 5 studies using HP did not find a statistical reduction in CDI rates.[53] Perhaps the most significant limitation in the use of HP robot technology is the total procedural time required (approximately 1.5-8.0 hours) due, in part, to room setup which requires occlusion of doorways and vents. Additionally, all these automated supplemental systems cannot be used in the presence of persons in the room and require dedicated staff to perform the function.

Another promising supplemental disinfection technology is the electrostatic sprayer which can be used to apply any sporicidal disinfectant directly on equipment and other environmental surfaces in various health care areas. A recent study using this type of device demonstrated a >6 log reduction against *C difficile* and a SARS-CoV-2 surrogate.[54]

Understanding the operating parameters of mobile environmental disinfecting technology has led science to the next evolutionary level in decontamination concepts. Research engineers have designed *continuous* disinfection technologies incorporated in room designs that emit either visible light at specific wavelengths or produce disinfecting emissions at levels that are not toxic to humans. "Blue light" in the spectrum of 400-470 nm has demonstrated a consistent 1- to 2-$\log_{10}$ reduction of surface bacteria.[55] A novel photocatalytic conversion device inserted into the ducts of an HVAC system, uses a multiwavelength ultraviolet light to illuminate target surfaces. The device is comprised of a honeycomb matrix treated with a photocatalytic coating of titanium oxide (TiO2) and other reactive metals. The device converts H_2O and O_2 in the air into hydroxyl radicals and HP which work to reduce bioburden on surfaces. In a published ICU-based study, a 95% reduction in average microbial burden, 81% reduction in the prevalence of MRSA, and a 54% reduction were reported in HAIs over a 4-month period.[56] Another study in 5 medical units using HVAC-installed devices that emit dry HP on a continuous basis demonstrated an overall 96.5% microbial reduction for all combined surfaces.[57] Regardless of the available technology, IPs need to acquire evidence-based information on the device's effectiveness in reducing contaminating microorganisms on health care environmental surfaces.

ANTIBIOTIC-RESISTANT ORGANISMS

Antibiotic-resistant organisms (AROs) are associated with 4.95 million deaths worldwide.[58] On December 7, 2021, the Centers for Disease Control and Prevention (CDC) announced that it has awarded $22 million to nearly 30 organizations around the world to combat antimicrobial resistance and other health care threats through the establishment of 2 new networks—the Global Action in Healthcare Network (GAIHN) and the Global AR Laboratory and Response Network (Global AR Lab & Response Network). ARO control is an international priority that requires all health care facilities and agencies to assume responsibility to prevent transmission. Such initiatives are driven by the fact that infections with AROs are associated with increased lengths of stay, costs, and, more importantly, mortality.[59]

IPs in coordination with other key health care personnel should review core information regarding AROs in order to determine facility policy on such issues as isolation, appropriate therapy, and antibiotic stewardship: ensure accurate microbiology test results using the latest Clinical and Laboratory Standards Institute (CLSI) determination of minimum inhibitory concentration (MIC) antibiotic breakpoints[60] (failure to implement these breakpoints may lead to negative impacts on patient care, infection control, as well as public efforts to limit the spread of such organisms)[61]; prioritize pathogens using WHO document that categorizes (Critical, High, Medium) resistant bacteria based on treatment options and potential for spread, for example, carbapenem-resistant *A baumannii, P aeruginosa, Enterobacteriaceae*[62]; or CDC's phenotype definitions[63] and Antibiotic Resistance Threats report.[64] In addition, AROs are detailed in the NHSN's Multidrug-Resistant Organism & *C difficile* Infection module which addresses AROs associated with HAIs.[65] "Enterobacterales" was adopted as a new taxonomy and scientific order in 2020. The microbiologic family of Enterobacterales includes Carbapenem-resistant Enterobacteriaceae (CRE) organisms. CRE bacteria pose a serious public health threat and are associated with high mortality due in part to limited antibiotic therapy. The principal CRE organisms include *Escherichia coli, Klebsiella pneumonia*, and *Enterobacter* spp.[66]

Organisms with newly identified antibiotic-resistant mechanisms continue to be identified throughout the world. Access to electronic communication across the continuum of health, for example, ambulatory to acute to long term care, by key health care personnel on emerging AROs is, therefore vital. IPs should assist in developing a procedural and administrative policy for transferring adult and pediatric patients identified with AROs, utilizing the CDC Inter-Facility Transfer guidelines for communication between hospitals, including out of state/territory facilities.[67]

One recent report identified an emerging "superbug" that was cultured from a patient in a Florida long-term care facility. The event was associated with a *P aeruginosa* isolate that was producing VIM (Verona integron-encoded metallo-beta-lactamase), an enzyme that makes it resistant to a class of antibiotics normally highly effective against antibiotic-resistant bacteria. This was Florida's first reported case, classified as VIM-CRPA, and immediate containment was necessary.[68]

It is critical to identify the specific pathogen in serious, life-threatening infections, especially for situations that are likely to require prolonged therapy. Due to the inherent time associated with microbiologic culturing methods, clinicians often use a standard empiric

antimicrobial therapy approach that often is composed of a regimen of 2 or more antibiotics administered at a time. Adverse outcomes associated with overuse of antimicrobials includes emergence of AROs and *C. difficile*. One of the top concerns for antibiotic stewardship endeavors is the delayed receipt of results of organism identification (ID) and antimicrobial susceptibility test (AST). Generally, such testing can take a microbiology laboratory from 48 to 72 hours, and in some circumstances a longer period due to the growth characteristics of the particular organism. Institutions should investigate the use of rapid diagnostic technology that reduces both ID (<1 hour) and AST (< 8 hours). Advancements in rapid diagnostics have shortened the time to results from days to hours and have had positive effects when paired with a transition from the use of broad-spectrum antimicrobial regimens to pathogen-specific therapy on clinical outcomes and on efforts to combat antimicrobial resistance.[69] Further advances, including the provision of point-of-care testing, along with increased funding and government initiatives, will require review in order to further close the gap between current culturing methods and rapid diagnostic results.

DECOLONIZING PATIENTS

Colonization with health care-associated pathogens such as *S aureus*, enterococci, and Gram-negative organisms, is associated with increased risk of infection. Decolonization is an evidence-based intervention whose goal is to reduce or eliminate the bacterial bioburden in order to reduce the risk of infection. Most decolonization interventions consist of a nasal product plus bathing with chlorhexidine gluconate (CHG). This section will focus on decolonization to reduce HAIs in the intensive care unit (ICU), noncritical care, and surgery.

In 2013, 3 randomly selected cluster trials on the topic of CHG bathing among ICU patients were published. One cluster-crossover study reported that daily 2% CHG cloth bathing in the ICU resulted in a 23% reduction of vancomycin-resistant E*nterococcus* (VRE) and methicillin-resistant *S. aureus* (MRSA) acquisition and a 28% reduction in bloodstream infections (BSIs).[70] In another study of pediatric ICU patients, Milstone et al found a significant association between 2% CHG cloth bathing and a decline in BSIs compared with standard bathing.[71] Another trial, called the REDUCE MRSA study, used a cluster-randomly selected methodology in 43 hospitals (including 74 adult ICUs) to evaluate 3 MRSA prevention interventions: the first cluster implemented MRSA screening and isolation, the second cluster included screening, isolation, and decolonization of MRSA carriers with CHG bathing and nasal mupirocin (ie, targeted decolonization), and the ICUs in the third cluster did not screen any patients but instead, all patients were decolonized with CHG cloth bathing and nasal mupirocin (ie, universal decolonization). Universal decolonization was found to be associated with the greatest decrease in all-cause BSIs (44%; $P < .001$) and rates of MRSA clinical cultures (37%; $P < .01$).[72] In a secondary analysis, CHG bathing was also shown to reduce blood culture contamination by 45% ($P < .02$), and to be the most cost-effective. In 2014, the Compendium on Strategies to Prevent Central Line–Associated Bloodstream Infections (CLABSI) in Acute Care Hospitals recommended bathing for ICU patients over 2 months of age with a CHG preparation daily (quality of evidence: I).[73]

Although the patient-specific risk is highest in ICUs, an equal number of CLABSIs occur in hospital units outside of the ICU. Questions remain about the use of ICU-proven strategies in noncritical care units. The ABATE Infection (active bathing to eliminate infection) trial, a 2-arm cluster randomly selected trial is the first and only large-scale cluster-randomly selected trial designed to evaluate whether universal CHG bathing for all patients plus targeted mupirocin for MRSA carriers in noncritical-care units reduces multidrug-resistant organisms and all-cause BSIs.[74] In the initial analysis there was no difference in MRSA and VRE clinical cultures or BSIs, but the posthoc analysis of the trial found that non-ICU patients with vascular access devices (central lines or midlines) had a significant 37% reduction in MRSA and VRE and a significant 32% reduction in all-cause BSI. Based on this study, many facilities implemented CHG bathing with or without mupirocin in patients in noncritical care units with vascular access devices. In 2019 the CDC recommended CHG plus an intranasal antibiotic/antiseptic product in patients with a central line or midline as a supplemental strategy in noncritical care.[75]

Surgical site infections (SSI) remain one of the most common and expensive HAIs, with *S aureus* among the most frequent etiologic pathogens. Studies confirm *S aureus* carriage increases the risk of *S aureus* SSIs. There is strong evidence that nasal and skin decolonization prior to cardiac and orthopedic surgery is effective in reducing SSIs caused by MSSA or MRSA. A recent study implemented a bundled intervention in 20 hospitals to prevent complex *S aureus* SSIs after cardiac surgery and hip and knee arthroplasty.[76] The bundle included preoperative screening for MRSA and MSSA nasal colonization, CHG bathing for all patients, nasal mupirocin decolonization for *S aureus* carriers, and both vancomycin and cefazolin perioperative antibiotic prophylaxis for MRSA carriers. The mean rate of complex *S aureus* SSIs significantly decreased by 42% from 36% infections per 10,000 operations during the baseline period to 21 infections per 10,000 operations during the intervention period (rate ratio 0.58; 95% CI, 0.37-0.92).

Moving forward, challenges related to decolonization include expansion of these strategies for additional surgical patient populations, as well as nonsurgical invasive procedures. For example, interventional radiology patients receiving implants such as cardiac implantable electronic devices (CIED) have been associated with significant numbers of postimplant infections, often caused by *S aureus*.[77] For patients known to be colonized with MRSA or MSSA prior to a CIED procedure, a multigroup British Working Party guideline recommends the use of nasal and topical antimicrobial agents preprocedure in order to suppress carriage.[78] Although mupirocin remains the best-studied nasal agent, there is some evidence on the use of safe and effective alternative agents such as povidone-iodine (PI),[79] alcohol-based nasal antiseptic,[80] as well as photodynamic therapy (PDT).[81] Although PI may be a useful alternative decolonizing agent for the prevention of *S aureus* infections, additional clinical data are required to further confirm the effectiveness of PI in preventing *S aureus* infections. There is only 1 alcohol-based study that was conducted at a single-center using a quasi-experimental design with historical controls. Lastly, photodynamic therapy is another promising approach for topical MRSA decolonization, but larger clinical trials are needed to evaluate different nasal decolonization protocols (including determining the optimal sensitizer) using clinically significant infection as the outcome.

In addition, there is a need to determine if the widespread use of CHG-based products promotes reduced CHG activity. Testing for CHG susceptibility is currently not standardized and the clinical impact of reduced chlorhexidine susceptibility in bacteria is unknown and not yet well-defined.

DECREASING CONTACT PRECAUTIONS

The recommended use of contact precautions (CPs) in acute care as a proposed strategy for preventing ARO transmission has been a mainstay for half a century with successes documented particularly when the organism is emerging rather than endemic.[82] However, recommended duration of CPs as a strategy for prevention in hospitals remains unsettled. Determining when CPs may be discontinued and thus safely reduce risk of transmission is influenced by 3 key factors. First, involves the organisms themselves: which antibiotic resistant bacteria trigger an isolatable condition, and whether the patient

is deemed colonized or infected with the particular ARO. Second, involves what type of isolation is applied. In nonhospital settings such as ambulatory clinics, dialysis centers, and home care settings recommendations for handling patients with AROs include use of standard precautions, while skilled nursing facilities deploy enhanced barrier precautions (use of Personal Protective Equipment [PPE], but without room restriction) for high contact care activities and CP when wounds or body fluids are unable to be contained or when ongoing transmission is suspected or confirmed.[83] The third factor involves whether a health care facility implements advances in health care strategies to reduce transmission risk or bioburden. Single patient rooms, alcohol-based hand sanitizers, hand hygiene monitoring protocols, supplemental environmental disinfection technologies (eg, ultraviolet/continuously active disinfection), dedicated/disposable medical equipment/devices, and patient decolonization with CHG bathing, nares decolonization and/or antiseptic oral rinse are some examples of interventions that may reduce the risk of transmission.[84] Currently, these strategies are neither uniformly nor equitably adopted across (or even within) health care facilities.

There has been a growing body of evidence indicating the development of potential unintended consequences (patient dissatisfaction, safety, and worsening noninfectious outcomes) with the use of CPs for AROs in a 1-size-fits-all approach.[85,86] A contemporary, popular approach has been to reserve CP for patients infected (vs colonized) with MRSA or VRE presumably under the hypothesis that colonization may correlate with a reduced organism density and therefore, reduced risk of transmission, the evidence in support of this specific hypothesis is not very strong.[87–89,] Meanwhile, there have been many reports of organizations suspending CPs without an increase in MRSA or VRE infection rates, often in the context of the aforementioned health care advances.[83] A recent SHEA expert guidance document regarding the duration of CPs acknowledges that "no universally recommended approach exists for making decisions regarding CP duration or discontinuation for any epidemiologically significant organism". The same document recommends that organizations develop ARO management policies including the use and duration of CPs in the context of their risks, priorities, and resources and that these policies be organism-specific, evaluated, and modifiable as/when/if the epidemiology changes.[89] What is lacking and needed is greater consensus on ARO transmission risk reduction strategies in the context of utilizing CPs judiciously for resource conservation and patient safety.

As mentioned, the list of AROs has expanded over the last 50 years and few would argue that further diversification is unexpected or that all AROs are equally transmissible. While suspending CPs for extended spectrum beta-lactamase (ESBL) Gram-negative organisms without an increase in ESBL infections has been reported,[90] this has not been as commonly reported with carbapenem resistant *Enterobacteriaceae* (CRE) though modeling in subacute settings suggest decolonization and screening for clearance may yield better results and no evidence to date with the recently emerged *Candida auris*.[91,92] Per the HICPAC meeting minutes of August 19, 2021, pertaining to the Isolation Precautions Guideline Workgroup and forthcoming efforts to provide further guidance, "Most of this will focus on the framing of transmission processes as opposed to the nitty gritty isolation practices. Airborne and contact isolation practices should not change." [93] This suggests that the way forward is a re-evaluation of the transmission modalities of AROs at the organism level (eg, MRSA vs CRE) and hopefully in the context of the aforementioned, disproportionally deployed advances in practice and technology. Decision support tools have been successfully utilized for infection prevention initiatives for years and are well suited for this challenge. Such tools could be developed and be evidence-based, algorithmic in nature and incorporate organism prevalence, health care setting and available control strategies including, but not exclusive to contact precautions.

DIAGNOSTIC STEWARDSHIP

Diagnostic Stewardship (DS) involves the ordering, collection, and timely reporting of diagnostic tests to improve treatment of infectious conditions. Suboptimal culturing practices can adversely impact patient safety and the quality of care in a wide variety of ways including: reporting of asymptomatic bacteriuria misidentified as urinary tract infection (UTI) and blood culture contamination mistaken for bloodstream infection resulting in a wrong diagnosis, increasing the numbers of AROs and *C difficile* as a result of overuse of antimicrobials, adverse reactions, and unwarranted financial expenditures stemming from inappropriate specimen testing and drug treatment, as well as the potential for over-reporting of HAIs such as catheter-associated urinary tract infections (CAUTIs).[94,95] Recent reviews and surveys examining urine and blood culturing practices have underscored this issue and have identified potential underlying causes.[96,97]

In order for health care organizations to optimize clinical and epidemiological outcomes related to urine and blood culturing, the CDC has recently identified key needs that will be essential to address, including the need for drivers to incentivize or require health care facilities to invest in DS, the need for meaningful measures development, and perhaps most important, the need for leadership support for implementation.[98] In addition, system-wide management programs must be directed by standardized practice guidelines, jointly written by IPs, microbiologists, and other key stakeholders, providing guidance in the preanalytic phase, that is, pathways for selecting the appropriate test according to patient's syndrome, methods for obtaining optimal collection of clinical specimens, and interpreting microbiology results.[99,100] In addition, efforts must be focused on education of nurses to understand the "why" behind proper culturing techniques,[101] and of physicians on appropriate ordering and interpretation of culture results.[102] Additionally, in order to ensure the integration of all areas of infection management (diagnosis, treatment, and prevention) a unified stewardship strategy is recommended such as reflected in the AID (antimicrobial, IP, and DS) model.[103] The basis of this model is the understanding that outcomes improve when providers understand and cooperate in implementing a system that promotes the appropriate test, the right interpretation of a test result, selection of the appropriate antimicrobial, and administration at the right time. [104] DS targets all relevant patient *populations*, for example, ensuring that established protocols capture both catheterized and noncatheterized patients relative to urine culture collection.[105] DS also targets all relevant patient *settings*, for example, in specimen-intensive areas such as Emergency Departments,[106] and focuses on prevention of overutilization of blood and urine cultures.[107] This can be accomplished in part by reviewing and revising order sets in electronic medical records (EMR) to reflect essential modifications such as urine culture reflex testing, a practice that reduces unwarranted urine cultures while continuing to provide accurate clinical findings,[108] and integration of electronic medical records to improve compliance with ordering protocols.[109] An important aspect of DS is ongoing evaluation of novel devices, such as those designed to reduce blood culture contamination.[110]

DS interventions should also be applied to *C difficile* testing to ensure more appropriate testing, facilitate prompt isolation and optimize clinical treatment. DS interventions related to *C difficile* testing should include: provision of education of nurses on the appropriate documentation of patient bowel movements and use of laxatives[111]; implementation of *C difficile* order sets[112] and EMR best practice alerts to assist providers in avoiding testing when patients do not meet current recommendations (recent laxative use, < 3 unformed stools in 24 hours)[113]; optimizing testing strategies to distinguish between toxigenic and nontoxigenic strains of *C difficile*. Specifically, the nucleic acid amplification test (NAAT) is a widely adopted laboratory diagnostic tool for *C difficile*, due to the high sensitivity and rapid

turnaround time of the testing methodology. However, when a NAAT is used as the sole testing method, misdiagnosis of *C difficile* infection can occur because the test does not distinguish between toxigenic and nontoxigenic strains of *C difficile*.[113] Therefore, best practice strategies should incorporate a 2-step reflex testing algorithm that utilizes advanced laboratory screening methodologies.

HAI SURVEILLANCE AND PREVENTION: BSI

Several important interventions are needed to achieve improvements in surveillance and prevention of BSI including expansion of the definition, improved documentation of clinical findings to prevent missed events and over-diagnosis,[114] identification of provider knowledge gaps followed by education to support the introduction of an enhanced central line maintenance bundle,[115] and evaluation of novel technologies including advanced antimicrobial IV dressings that may extend the effective antimicrobial period over the entire recommended duration of the dressing.[116] Future endeavors should include in vivo studies that test the effectiveness of advanced dressings in reducing BSIs.

Device-associated BSIs account for significant numbers of HAIs in United States health care facilities. However, the full extent of the problem is unknown because surveillance and federal reporting is currently mandated only for CLABSI events. Published studies indicate that considerable numbers of BSIs occur as a complication after placement of arterial,[117] hemodialysis,[118] midline,[119] and peripheral intravenous catheters (PIV).[120] This evidence supports a need to implement a more comprehensive prevention strategy that addresses *all* types of intravenous catheters, which could be captured using a concept known as *Hospital Onset Bacteremia* (HOB). This expanded prevention strategy should extend to settings outside of hospitals, such as home infusion, where caregiver practices are a notable infection factor.[121] It should also reflect recent learnings from the COVID-19 pandemic based on analysis of the causes for the increase in BSI during this period.[122]

HAI SURVEILLANCE AND PREVENTION: NONVENTILATOR HOSPITAL ACQUIRED PNEUMONIA

Nonventilator hospital acquired pneumonia (NV-HAP) is the most common hospital acquired infection in the US affecting 1% of hospitalized patients with a crude mortality rate of 15%-30%.[123,124] NV-HAP is associated with a significantly longer length of stay, high 30-day readmission rates, a greater need for intensive care management and long-term care following discharge, increased direct care costs, and perhaps most importantly, it is a frequent source of sepsis.[124-126]

As noted in a September 2021 Joint Commission Safety Briefing, NV-HAP is a substantial threat to patient safety and a large driver of health care cost, yet it is not formally tracked or reported to the National Database of Nursing Quality Indicators or the CDC NHSN nor does it impact the Centers for Medicare and Medicaid Services pay-for-reporting or performance programs.[127] NV-HAP surveillance is not currently standardized, and risk stratification is not reliable, therefore, consideration should be given to application of universal prevention guidelines throughout every patient's hospital or long-term care stay.[124,127] The most promising evidence-based prevention measures include primary source control (eg, oral care), early and frequent ambulation, head of a bed elevation, and aspiration precautions.[123,126-128] Additional randomly selected controlled trials evaluating the impact of individual interventions (rather than a "bundle") are warranted.[124,128] However, it is equally important to help health care facilities improve quality and safety now and develop practical prevention strategies to translate existing evidence into practice to improve the health and safety of patients.[124,127]

NV-HAP prevention recommendations include engaging facility leadership and interdisciplinary team members in discussions about the importance of NV-HAP surveillance and prevention, considering provision of adequate resources, and facilitating implementation of evidence-based interventions, nursing documentation templates on NV-HAP prevention that capture process measures and an electronic tracking system to monitor NV-HAP. Other measures include mentoring influential nurses and nursing assistants in direct care positions to serve in leadership roles (including those who are not in official management positions) to champion prevention efforts within the daily workflow, raising the profile of oral care as a new standard and an essential infection prevention practice rather than an optional comfort measure, and supporting a safety culture by facilitating regular reminders and communication, particularly in areas with high staff turnover. Lastly, maintaining staff education and competencies in fundamental nursing care (eg, oral care, mobility), creating an efficient process to stock needed supplies and equipment at the bedside, empowering patients to ask for assistance with oral care, feeding, and mobility when they need it and to report when they completed their care independently so it can be documented, and establishing the prevention plan as a standard of practice facility wide.[124,129,130]

HAI SURVEILLANCE AND PREVENTION: VENTILATOR-ASSOCIATED EVENTS

For many years IP programs conducted surveillance for ventilator-associated pneumonia (VAP) using an NHSN definition that included several clinical components that were often subjective and difficult to interpret.[131] In 2013, the VAP definition changed to a tiered system represented by ventilator associated events (VAE),[132] subcategorized by objective criteria for infection-related ventilator associated condition and then more specifically by possible and probable VAP. The VAE definition eliminates subjectivity by using clearly defined criteria often contained in medical records and therefore, facilitates the automated collection of data.[133] Additionally, VAE definitions broadened the focus of surveillance from pneumonia alone to the syndrome of nosocomial complications in ventilated patients.[134]

However, the current tiered VAE definition lacks sensitivity, potentially resulting in underreporting of true events. An initial goal of the VAE definition was to identify all causes of respiratory deterioration as well as broadening the safety surveillance for patients on a ventilator including pneumonia, atelectasis, fluid overload and acute respiratory distress syndrome. A meta-analysis by Fan et al determined the pooled sensitivity of VAE for traditionally defined VAP was 42%.[135] Additionally, the pooled positive predictive value of VAE for traditionally defined VAP was 23%. Another study by Zosa et al identified that the VAE definition grossly underestimates the clinical diagnosis of VAP and reports less than a third of the patients treated for VAP.[136] The fact that VAE surveillance misses many traditionally defined VAPs would appear to undermine its claim to detect clinically important respiratory complications of care. Enhancing surveillance and intervention protocols are supported by the severe consequences of such infections: VAPs have a significant attributable mortality (4.6%) along with increases in morbidity, hospital length of stay (LOS) and cost of care.[133]

When the VAE definition was implemented, its purpose was not to be a method to specifically identify VAP but rather to broaden safety surveillance for a variety of ventilator-associated events. Updated definitions will enhance consistency, accuracy, and reproducibility of surveillance information.[137] A collaborative effort among the IP community and NHSN with the aim to enhance a balance between epidemiological and clinical occurrences based on expert review should increase infection sensitivity, leading to broader and more effective prevention efforts, as well as raising event agreement among respiratory therapists, intensivists, and IPs.

HAI SURVEILLANCE AND PREVENTION: URINARY TRACT INFECTIONS

UTIs represent a common diagnosis for patients in the ambulatory, acute, and long-term care settings. Contrary to the evaluation of patients for bacteremia where blood is normally sterile, colonization of the urine increases with age and is considered physiologic. Asymptomatic bacteriuria (AB) is prevalent with older age, diabetes, impaired voiding, and urinary catheterization.[138] A widespread practice is to obtain a urine specimen for analysis for both infectious and noninfectious conditions. The urinalysis, commonly used to test for noninfectious conditions, includes metabolic, inflammatory, and renal components. Some elements indicating bacteriuria (eg, nitrites), and others reflecting inflammation (eg, leukocyte esterase) are often mistakenly equated with infection triggering the order of a urine culture. Almost half of patients admitted to hospitals have a urinalysis performed and a quarter will have a urine culture done.[139] Obtaining a urine culture without an evaluation of the patient clinical condition and the likelihood of symptomatic urinary tract infection leads to misdiagnosis, inappropriate antimicrobial use, and increase the risk for antimicrobial resistance. In addition, variation in testing occurs based on setting. In the ambulatory arena, often a UTI is diagnosed based on clinical grounds, and urine culture may not be obtained for the first episode of cystitis. The elderly, especially those that reside in long-term care facilities, have a high prevalence for AB, and are prone for misdiagnosis of UTI when clinical parameters are not included in the decision making to test.[140] On the other hand, the clinically defined catheter-associated UTI (CAUTI) is reached by excluding other diagnoses.[141]

The main challenge in addressing UTI relies on the importance of incorporating clinical signs and symptoms as cardinal factors, with laboratory support, to reach the diagnosis. DS starts with a focus on the preanalytic component which is heavily dependent on clinician knowledge and competencies. Understanding the pretest probability before obtaining a urinalysis or culture, and incorporating the patient's symptoms in the decision to order the test will reduce the likelihood of detecting patients with AB.[142] Specimen contamination is minimized by obtaining a clean midstream sample for those noncatheterized and a fresh specimen from sampling port in those catheterized. The analytic phase is where the laboratory can actively support unnecessary testing by limiting urine cultures to those ordered for urinary symptoms.[143] The absence of pyuria on a urinalysis is predictive of not having a symptomatic UTI. Different algorithms have been implemented in hospitals to reduce the unnecessary use of urine cultures based on the quantitative evaluation of pyuria on a urinalysis. However, the cutoff for pyuria to adequately exclude asymptomatic bacteriuria is still not clear, and it is uncertain if using the urinalysis to decide whether a culture is warranted discriminates adequately between those with or without a clinical infection.[144] Reflex urine cultures should only be performed for patients with suspected symptomatic UTI, and not only based on the urinalysis results. Exclusions include pregnancy and urologic procedures associated with mucosal trauma.[138] In the postanalytic phase, framing the culture results and the corresponding antimicrobial susceptibilities in context will help enhance the clinician's decision making.

DS is a prerequisite to achieving successful antimicrobial stewardship outcomes. We need to promote standardized processes to improve the diagnostic testing of patients with suspected UTI. First, clinicians need to eliminate the old habits of "panculturing" to a more reflective behavior where testing the urine is based on suspicion of infection. Second, the use of "urinalysis with reflex to culture" requires more research to standardize the parameters that would trigger a culture. Third, future process measures to evaluate the variation in utilization of urinalysis and urine culture may help understand the under- and over-use of diagnostic tools. Fourth, in the hospital setting, more inclusive metrics such as the standardized utilization ratio (SUR) are useful tools to evaluate both infectious and noninfectious device risk. From an outcome measure perspective, the current surveillance definition, especially for CAUTI, suffers from a low positive predictive value for true instances of disease, leading to skepticism from clinicians. More objective, electronically captured data, such as combining patient-level catheter-associated bacteriuria and antimicrobial use may help better understand the stewardship and infection prevention problem.[145] Finally, in the ambulatory or long-term settings, evaluating the incidence of UTI and associated antimicrobial treatment of populations at risk for misdiagnosis (eg, diabetics, elderly) may provide valuable information on potential future areas of focus.

HAI SURVEILLANCE AND PREVENTION: SURGICAL SITE INFECTIONS

One well studied approach to improving surgical patient outcomes is the use of care bundles. The care bundle concept was first introduced into the surgical arena by the Institute for Healthcare Improvement (IHI) in 2006 as a strategy to reduce the risk of SSI and was based upon 4 core measures: (1) timely and appropriate antimicrobial prophylaxis, (2) appropriate hair removal, (3) normothermia, and (4) glycemic control (focusing at that time on vascular and cardiac patients). While each of these measures had a relevant evidence base, together they were not sufficiently robust to lead to a sustainable improvement in patient outcome across the surgical spectrum.[146]

However, over time with the addition of key elements, the surgical care bundle (SCB) has emerged as an accepted method of packaging the best, evidence-based measures into routine care for all surgical patients to prevent SSIs. Most of the selective evidence-based measures listed below have been identified by systematic review and meta-analyses, providing moderate to high clinical evidence (1A) and recommended in national, international and societal guidelines.[147] Currently, there is no consensus as to the maximal number of measures within an evidence-based surgical care bundle. However, consensus suggests that individual care bundle components should attempt to address the myriad of patient risk factors present at the time of surgery.

One bundle measure supported by several evidence-based studies in selective surgical disciplines is a standardized preadmission shower/cleansing strategy using CHG to reduce the microbial burden on the surface of the skin at the time of surgery. This should be viewed as adjunctive to perioperative skin antisepsis protocols (ie, skin prep) which is a separate SSI prevention care bundle measure.[148] The 2021 AORN Guideline for Preoperative Patient Skin Antisepsis states the following: (1) follow manufacturer instructions for use (IFU) and safety sheet for prepping, handling, safety and storage; (2) establish a standardized skin prepping protocol that includes a selected skin marking strategy; (3) confirm the surgical site and isolated contaminated sites prior to prepping with a barrier drape; (4) apply surgical skin prep agent using sterile technique and sterile supplies, starting at incision site and move outwards; (5) implement patient and staff safety measures such as minimizing the risk of fire, especially with alcohol-based products; (6) at end of procedures, assess patient skin for injury after removing skin antiseptic agent; (7) document prep in the EMR.[149] The 2013 Antimicrobial Prophylaxis Guidelines were developed jointly by the American Society of Health-System Pharmacists (ASHP), the Infectious Diseases Society of America (IDSA), the Surgical Infection Society (SIS), and the Society for Healthcare Epidemiology of America (SHEA). For the first time, this document addresses weight-based considerations to insure maximal tissue concentrations within the wound bed during the intraoperative period.[150]

Another bundle measure shown to reduce the incidence of SSIs, especially in high-risk surgery involving implants such as knee and hip arthroplasty is the screening of patients for both MSSA and MRSA nasal colonization. While mupirocin has been for many years the standard agent for nasal decolonization, studies using nasal povidone iodine (5% or 10%) or a novel alcohol-based (70%) nasal antiseptic have been documented to be effective in reducing staphylococcal nasal colonization but further clinical investigations are warranted.[151] In addition, perioperative supplemental oxygen (80%) or hyperoxia is a recognized bundle measure, as it increases tissue oxygen tension, which may lead to an increase in oxidative killing of surgical pathogens and a reduction in SSIs. Current national, societal and international guidelines are supportive of perioperative hyperoxia to reduce SSIs in colorectal surgery patients.[152] The SSI prevention care bundle element related to the patient's core temperature recommends monitoring throughout the surgical procedure and with maintenance of normothermia preoperatively, intraoperatively, and postoperatively. Hypothermia is defined as a core temperature below 36 °C and patients should be prewarmed a minimum of 30 minutes prior to the induction of anesthesia.[153] The presence of diabetic hyperglycemia at the time of surgery is a significant risk factor across the spectrum of surgical disciplines, so glycemic control is yet another evidence-based SSI prevention care bundle element. Hemoglobin A1C represents a more accurate indicator of glycemic control than blood glucose. Preoperative and inpatient diabetes management improves glycemic control on the day of surgery and postoperatively, decreasing the incidence of hypoglycemia which leads to improved clinical outcome.[154]

A systematic literature review (SLR) and meta-analysis identified 15 randomly selected controlled trials, producing a risk ratio of 0.67, 95% CI 0.54-0.84 ($P \leq .001$), demonstrating that use of antimicrobial coated/impregnated sutures were effective in demonstrating a statistically significant, lower risk of SSI in clean, clean-contaminated and contaminated surgical procedures.[155] Two recent studies have documented that use of an antimicrobial suture for wound closure as part of an evidence-based surgical care bundle can provide a significant fiscal benefit to the hospital and third party-payer, suggesting that antimicrobial sutures should be considered for both superficial and deep layer closure after all surgical operations.[156,157]

EMERGING PATHOGENS

The National Institute of Allergy and Infectious Diseases defines emerging infectious diseases “as infectious diseases that have newly appeared in a population or have existed but are rapidly increasing in incidence or geographic range”.[158] Although these emerging pathogens may be well studied in laboratory settings, by definition, when they emerge in populations that have not had prior exposure or experiences with such diseases, the public, as well as IP programs are woefully unprepared to address the public health implications and, in turn, the socio-economic ramifications of being so ill-prepared. IP programs find themselves all too often being reactionary rather than proactive in the light of emerging pathogens. Two very different but recent examples can be seen with Ebola and COVID-19. First identified in 1976, the CDC describes 33 outbreaks in 19 countries of the Ebola viral hemorrhagic fever (including the 3 species that cause disease in humans: Zaire, Sudan, and Bundibugyo; and 1 species that does not cause disease in humans, Reston) prior to the Ebola outbreak of 2014.[159] Although this pathogen was known for 38 years, when Ebola was first diagnosed in a patient admitted to a hospital in Texas, United States (US), it was evident that infection prevention programs were not prepared to properly control potential transmission. Transmitted through infected body fluid, PPE took on a new meaning for front-line staff, including the importance of selecting the correct PPE, as well as conducting extensive training to learn the proper process of donning and doffing PPE to reduce the risk of blood or body fluid contamination. In addition, special arrangements in terms of the patient care environment were needed to address the patient’s isolation room, temporary “mini-labs” where testing can be run by specially trained staff, 1-way traffic flow to prevent accidental contamination, nearby emergency showers for staff in the event of an exposure, and special waste management precautions. More recently, in December 2019, when COVID-19 first appeared in California and rapidly spread across the United States, it quickly became apparent that the US public health and health care infrastructure were not designed to provide rapid identification of infected individuals, control transmission among the vulnerable population, and manage and treat large surges of patients in our health care facilities. Emerging pathogen events have underscored the need for IP programs to emerge from positions of remaining reactive to becoming proactive by developing robust systems capable of properly handling future pandemic diseases.

As described by Abouleish, a lack of information, conflicting information, unfamiliarity with the disease, along with human perception all work together to formulate a perceived risk level of disease transmission.[160] This helps explain, in part, acceptance, or lack thereof, of infection prevention measures by the public. In the context of the latest pandemic, universal infection prevention and control approaches to reduce disease transmission in the health care setting focus on: (1) early identification and appropriate isolation of patients suspected of having the disease through symptom screening or testing; (2) universal source control through mandatory masking to contain respiratory droplets; (3) quarantine after exposure; (4) the use of appropriate personal protective equipment; and (5) appropriate environmental decontamination.[161,162]

Airborne infection isolation rooms (AIIR), formerly known as negative pressure isolation rooms, are designed to protect other patients and health care team members from diseases transmitted via the airborne route. Most facilities are designed with few AIIR in comparison to standard rooms, and as a result, these were rapidly allocated during the surges of COVID-19.[163] Soon, infection prevention programs found themselves working creatively to develop geographic cohorts (entire units made up of patients with a common infectious disease) or find ways to create more AIIRs, for example, by using portable HEPA scrubbers or changing the ventilation dynamics of a particular unit or floor. Through the course of the pandemic, research has found that the large majority of COVID-19 virus is spread via respiratory droplets that drop precipitously within 6 feet of the infected, not only putting unprotected individuals at risk within that 6-foot space, but also able to contaminate the environment near infected individuals.[161] However, the relationship of finding virus particles in the environment and the role these particles play in the ability to cause disease requires further investigation.

Aerosol generating procedures (AGP) have gained considerable attention since the pandemic began. Yet there remains poor consensus and conflicting evidence on which specific procedures should be considered AGPs, and to what extent these procedures can or do, pose the greatest risk in COVID-19 transmission.[162] The answer undoubtedly lies within a spectrum of factors that contribute to determining acceptable or nonacceptable risk. As an example, nebulizers, which by design aerosolize medicine for patient inhalation, have not been fully researched to determine their association with disease spread given such elements as variation in disease state of the host and ventilation/air quality of the surrounding environment. Optimal air quality includes having minimum fresh air exchanges —adequate ventilation is considered to be 60 liters/s/patient (AGPs not performed)[162] which may not always be possible, especially given a surge situation. Manufacturers of technologies that use HEPA or Ultra-HEPA filtration, ultraviolet-C radiation, and various combinations of other technology promise to rid the air of impurities and kill

airborne infectious agents, often with a paucity of concrete data in practical applications. Although scientific evidence conducted in laboratory settings has supported the effectiveness of these technologies, there is a need for new research and validation that these technologies delivered in real-world settings can verify these claims.

An additional important issue concerns the interplay between emerging pathogens and PPE. As the COVID-19 pandemic progressed rapidly through the first year, the extremely high demand for, and subsequent lack of, PPE forced many infection prevention programs to develop policies and practices related to extended use and re-use of PPE. To meet the need, infection preventionists were forced to reevaluate disposable PPE and develop various methodologies of extending their use or reprocessing single-use equipment so it could safely be used again. Most notably, reprocessing filtering facepiece respirators (FFR) became exceedingly important. A systematic literature review identified 14 methods for decontaminating FFR, with 4 predominant methods surfacing: ultraviolet germicidal irradiation, moist heat, microwave-generated steam, and hydrogen peroxide vapor.[163–166] In addition, cautionary tales of using the various technologies that decontaminate respirators may indeed alter their performance.[164,167] Further research is needed to ensure that decontamination and reuse of PPE can be done effectively and efficiently without compromising safety. Alternatively, identifying existing PPE or developing new PPE that can be worn safely and effectively for extended periods of time (such as powered air-purifying respirators) should be further investigated.

Despite attempts at understanding how to handle IP issues associated with COVID-19, the financial ramifications incurred by health care institutions due to the pandemic may represent the greatest ongoing challenge. The impact incurred by rising operating costs and decreasing revenue may very well translate into reduced budgets for programs such as infection prevention. This may present itself with cuts to IP staffing, infrastructure resources, product limitations, or pauses in innovative technologies.[168,169]

CONCLUSION

Fifty years of IP evolution has brought us to a crossroads in which we face increasingly diverse and complex issues. This article addresses many of those issues, providing insight on how to more effectively improve IP programs, standardize metrics, and better control potential HAI events in the future. (Table 1 summarizes recommendations for change in 14 topics of concern.) These advances must be accomplished with the understanding of the importance of a structure for infection prevention nationally that spans across the continuum of care from acute to skilled nursing to ambulatory to postacute settings and which is resilient to mammoth events such as pandemics. Regardless of which strategies are considered, IP successes will depend largely on strong leadership support. A recent analysis of management methods identified 3 practices as important facilitators in the prevention of HAIs[170]: First involves engagement of executive staff. Establishment of IP goals by executive leadership emphasizes an organizational priority among managers and frontline staff and enables open communication with persons who are empowered to make change. Second addresses information sharing. Establishment of an organization-wide system to relay, display, and discuss relevant infection data with frontline staff is an important activity. Third involves management coaching. The coaching activities identified as most needed involve providing staff with feedback on how to perform clinical care processes correctly and re-educating staff on best practices for IP. The future success of IP programs will therefore, lay in identifying and implementing cutting edge program modifications and best practices while supported by targeted executive actions.

Table 1
Recommendations for change in infection prevention programs and practice

IP Program Standardization	• Based on outcomes based scientific research (eg, HAI rates, process compliance, patient satisfaction), establish a standard template for IP programs to support the replication of best practices, avoid errors, and optimize processes. • Conduct research focusing on determining IPs time allocation taking into account variability between health care facilities. • Conduct research into IP program reporting structure. • Establish a certification process for physicians in IP programs. • Conduct research to determine ideal IP staffing levels based on essential program components.
Surveillance	• Establish a collaborative association between NHSN and the IP community to evaluate HAI definitions in order to increase accuracy and reflect quality of clinical care and processes. • Conduct research into methods and training regimens to improve accuracy when conducting manual surveillance. • Establish a collaborative association between vendors of automated surveillance software and the IP community to evaluate the standardization and improvement of HAI accuracy across all available platforms.
Hand hygiene	• Review available national and international programs addressing behavior modification of health care personnel for improving hand hygiene. • Review published studies on hand hygiene improvement strategies that include enhancements in education, monitoring, infrastructure, and culture. • Consider the use of automated hand hygiene systems designed to assist in the verification of compliance while providing the ability to track compliance history.
Environmental Contamination	• Review studies addressing limitations in environmental cleaning and conduct a gap analysis to determine which factors need to be addressed. • Implement new strategies based on societal guidelines including those addressing the education of EVS staff to increase cleaning and disinfection. • Establish facility-specific acceptable levels of cleaning and disinfection. • Consider the use of supplemental disinfection technologies taking into consideration. such factors as cost, staffing needs, time allotments, and effectiveness of disinfection process.
Antibiotic Resistant Organisms	• Using key national and regional information, establish facility-specific listing of AROs integrating such information into the EMR in order to expedite isolation, therapy strategies, and antimicrobial stewardship program review. • Ensure that the facility receives state and local public health organizations' timely information on emerging AROs.

(*continued*)

	• Consider the use of rapid diagnostic technology for AROs; such technologies reduce both identification and antibiotic susceptibility time, therefore expediting isolation protocols and narrowing antibiotic therapies.
Decolonizing Patients	• Consider the use of a universal decolonization strategy for ICU patients (strategy includes use of CHG bathing in conjunction with a nasal antibiotic/antiseptic regimen). • Consider the use of a decolonization strategy for non-ICU patients with vascular access devices (strategy includes use of CHG bathing with or without the use of a nasal antibiotic/antiseptic regimen). • Consider the use of a decolonization strategy for patients undergoing cardiac and orthopedic surgery. • Consider the use of a decolonization strategy for patients receiving CIED implants; Conduct further research on decolonization strategies for patients receiving other types of implants.
Decreasing Contact Precautions	• Discontinuing CPs requires health care facilities to assess which AROs are isolatable and under what conditions (colonized or infected), type of isolation initiated (standard precautions, enhanced barrier precautions, etc), and whether supplemental strategies are used that may reduce the risk of transmission. • Health care facilities should establish protocols for discontinuing CPs based on ARO transmission risk, organizational priorities, and resources.
Diagnostic Stewardship	• In order for health care facilities to invest in DS, there will be a need for the establishment of drivers to incentivize implementation, the development of meaningful measures, and directed leadership support. • Establish system-wide standardized practice guidelines, jointly written by IPs, microbiologists, and other key stakeholders, providing guidance in the pre-analytic phase, that is, pathways for selecting the appropriate test according to patient's syndrome, methods for obtaining optimal collection of clinical specimens, and interpreting microbiology results. • Implement educational efforts on education of nurses to understand the "why" behind proper culturing techniques, and of physicians on appropriate ordering and interpretation of test results. • In order to ensure the integration of all areas of infection management (diagnosis, treatment, and prevention), establish a unified stewardship strategy such as reflected in the AID (antimicrobial, IP, and DS) model. The basis of this model is the understanding that outcomes improve when providers understand and cooperate in implementing a system that promotes the appropriate test, the right interpretation of a test result, selection of the appropriate antimicrobial, and administration at the right time. • Revise order sets in EMRs to reflect essential modifications in testing, to include urine and blood culture ordering and management protocols. • Consider evaluating novel methods to reduce blood culture contamination. • DS interventions related to *C difficile* testing should include provision of education to clinicians on what constitutes clinically significant diarrhea, the appropriate documentation of patient bowel movements and use of laxatives, implementation of *C difficile* order sets and EMR best practice alerts to assist providers in order to optimize testing and enhance the identification of patients with active disease, and not colonization.
HAI Surveillance and Prevention: Bloodstream Infections	• Establish collaborative association between NHSN and the IP community to evaluate BSI definitions in order to increase accuracy and reflect quality of clinical care and processes. • Conduct a gap analysis and knowledge assessment to determine educational and process needs, followed by institution of enhanced maintenance practices. • Consider evaluating novel technologies that extend the effective antimicrobial period over the entire recommended duration of an IV dressing. • Expand NHSN surveillance utilizing the model *Hospital Onset Bacteremia*, an initiative that captures BSI events not only related to central lines but to all types of intravascular catheters; such a strategy may be considered for application to other health care settings such as extended care facilities.
HAI Surveillance and Prevention: Nonventilator Hospital Acquired Pneumonia	• Establish a collaborative association between NHSN and the IP community to review published information on the occurrence of NV-HAP events, draft definitions, and to consider surveillance trials. • Consider establishing universal prevention measures including oral care, early and frequent ambulation, head of bed elevation, and aspiration precautions.
HAI Surveillance and Prevention: Ventilator Associated Events	• Establish a collaborative association between NHSN and the IP community to evaluate VAE definitions in order to increase accuracy and reflect quality of clinical care and processes. • Establish a collaborative association between NHSN and the IP community to facilitate the transition to institute ventilator-associated pneumonia as a requirement for national reporting, a measure that would incentivize prevention initiatives.
HAI Surveillance and Prevention: Urinary Tract Infections	• Establish a collaborative association between NHSN and the IP community to evaluate UTI definitions in order to increase accuracy and reflect quality of clinical care and processes. • Establish comprehensive education programs for clinicians emphasizing such important preanalytic issues as understanding pretest probabilities before obtaining a urinalysis or culture and incorporating the patient's symptoms in the decision process regardless of the clinical setting. • Establish standardized methods of urine collection for both catheterized and noncatheterized patients. • Establish laboratory processes for carefully reviewing urinalysis findings prior to processing a urine specimen for culture. • Conduct research to better understand the urinalysis parameters that should trigger a urine culture. • Conduct research to better understand the incidence of UTI and associated antimicrobial treatment in populations at risk for misdiagnosis (eg, ambulatory or long-term settings).
HAI Surveillance and Prevention: Surgical Site Infections	• Consider establishment of an advanced, evidence-based surgical care bundle, with new measures to include preadmission CHG shower/cleansing, weight-based antimicrobial

(*continued*)

Emerging pathogens	prophylaxis, a nasal decolonization strategy, perioperative supplemental oxygen, maintenance of normothermia, glycemic control, and use of antimicrobial sutures. • Conduct research addressing the appropriate control of patients with emerging diseases to include methodologies to improve early identification, surge management, isolation including use, necessity, and alternate technologies for AIIRs, transportation of patients, selection, proper use, and reprocessing issues related to such PPE items as facepiece respirators, employee exposure management, waste management, internal and external communication enhancement, initiation and duration of quarantine, effective environmental decontamination, and identification of AGPs that pose greatest risk of organism transmission.

AGP, Aerosol generating procedures; *AIIR*, Airborne infection isolation rooms; *ARO*, antibiotic-resistant organism; *BSI*, Bloodstream Infections; *CHG*, chlorhexidine gluconate; *CIED*, cardiac implantable electronic devices; *CPs*, contact precautions; *DS*, Diagnostic Stewardship; *EMR*, electronic medical records; *EVS*, environmental services staff; *HAI*, healthcare associated infections; *IP*, infection prevention; *NV-HAP*, Nonventilator hospital acquired pneumonia; *NNHS*, The National Healthcare Safety Network; *PPE*, Personal Protective Equipment; *UTI*, Urinary tract infection; *VAE*, ventilator associated events.

STATEMENT

The views of the authors may not be representative of the corresponding institutions.

References

1. Centers for Disease Control and Prevention. 2019 National and State Healthcare-Associated Infections Progress Report. Centers for Disease Control and Prevention. https://www.cdc.gov/hai/data/portal/progress-report.html. Accessed February 6, 2022.
2. Lee MH, Lee GA, Lee SH, et al. Effectiveness and core components of infection prevention and control programmes in long-term care facilities: a systematic review. *J Hosp Infect*. 2019;102:377–393.
3. Centers for Disease Control and Prevention. Creating a Business Case for Infection Prevention. Centers for Disease Control and Prevention. https://www.cdc.gov/infectioncontrol/pdf/strive/BC101-508.pdf. Accessed February 6, 2022.
4. Dick A, Perencevich EN, Pogorzelska-Maziarz M, et al. A decade of investment in infection prevention: a cost effectiveness analysis. *Am J Infect Control*. 2015;43:4–9.
5. Storr J, Twyman A, Zingg W, et al. Core components for effective infection prevention and control programmes: new WHO evidence-based recommendations. *Antimicrob Res Infect Control*. 2017. https://aricjournal.biomedcentral.com/articles/10.1186/s13756-016-0149-9. Accessed February 6, 2022.
6. Billings C, Bernard H, Caffrey L, et al. Advancing the profession: an updated future-oriented competency model for professional development in infection prevention and control. *Am J Infect Control*. 2019;47:602–614.
7. Agency for Healthcare Research and Quality. AHRQ Plan for Translating Research into Practice. Agency for Healthcare Research and Quality. https://www.ahrq.gov/topics/translating-research-practice-trip.html. Accessed February 6, 2022.
8. Dahlke JD, Mendez-Figueroa H, Maggio L, et al. The Case for standardizing cesarean delivery technique: seeing the forest for the trees. *Obstet Gynecol*. 2020;136:972–980.
9. McLachlan S, Kyrimi E, Dube K, et al. Towards standardization of evidence-based clinical care process specifications. *Health Informatics J*. 2020;26:2512–2537.
10. Murphy DM, Hanchett M, Olmsted RN, et al. Competency in infection prevention: a conceptual approach to guide current and future practice. *Am J Infect Control*. 2012;40:296–303.
11. Pogorzelska-Maziarz M, Gilmartin H, Reese S. Infection prevention staffing and resources in U.S. acute care hospitals: results from the APIC MegaSurvey. *Am J Infect Control*. 2018;46:852–857.
12. Scheckler WE, Brimhall D, Buck AS, et al. Requirements for infrastructure and essential activities of infection control and epidemiology in hospitals: a consensus panel report. *Infect Control Hosp Epidemiol*. 1998;26:47–60.
13. Bryant KA, Harris AD, Gould CV, et al. Necessary infrastructure of infection prevention and healthcare epidemiology programs: a review. *Infect Control Hosp Epidemiol*. 2016;37:371–380.
14. McQuillen DP, MacIntyre AT. The value that infectious diseases physicians bring to the healthcare system. *J Infect Dis*. 2017;216:S588–S593.
15. Bartles R, Dickson A, Babade O. A systematic approach to quantifying infection prevention staffing and coverage needs. *Am J Infect Control*. 2018;46:487–491.
16. Dhar S, Sandhu AL, Valyko A, et al. Strategies for effective infection prevention programs: structures, processes, and funding. *Infect Dis Clin Am*. 2021:531–551.
17. Centers for Disease Control and Prevention. About NHSN. Centers for Disease Control and Prevention. https://www.cdc.gov/nhsn/about-nhsn/index.html. Accessed February 6, 2022.
18. Maaike SM, Pleun VD, Karel GM, et al. Accuracy of administrative data for surveillance of healthcare-associated infections: a systematic review. *BMJ Open*. 2015. https://bmjopen.bmj.com/content/bmjopen/5/8/e008424.full.pdf. Accessed February 6, 2022.
19. Hebden JN. Slow adoption of automated infection prevention surveillance: are human factors contributing? *Am J Infect Control*. 2015;43:559–562.
20. Wright MO, Allen-Bridson K, Hebden JN. Assessment of the accuracy and consistency in the application of standardized surveillance definitions: A summary of the *American Journal of Infection Control* and National Healthcare Safety Network case studies, 2010–2016. *Am J Infect Control*. 2017;45:607–611.
21. Streefkerk HRA. Electronically assisted surveillance systems of HAIs: a systematic review. *Euro Surveill*. 2020;25:1–16.. https://www.eurosurveillance.org/docserver/fulltext/eurosurveillance/25/2/eurosurv-25-2-4.pdf?expires=1640276294&id=id&accname=guest&checksum=33338E116E2BA13EFB4459ABA7B7C132. Accessed February 6, 2022.
22. Sips ME. Automated surveillance of HAIs: state of the art. *Curr Opin Infect Dis*. 2017;30:425–431.
23. Chassin MR, Mayer C, Nether K. Improving hand hygiene at eight hospitals in the United States by targeting specific causes of noncompliance. *Jt Comm J Qual Patient Safety*. 2015;41:4–12.
24. World Health Organization. Improving Hand Hygiene Through a Multimodal Strategy. World Health Organization. apps.who.int/iris/handle/10665/70030. Accessed April 7, 2022.
25. Werzen A, Thom K, Robinson G, et al. Comparing brief, covert directly-observed hand hygiene compliance monitoring to standard methods: a multicenter cohort study. *Am J Infect Control*. 2019;47:346–348.
26. Tartari E, Fankhauser C, Masson-Roy S, et al. Train-the-Trainers in hand hygiene: a standardized approach to guide education in infection prevention and control. *Antimicrobial Res Infect Control*. 2019. https://aricjournal.biomedcentral.com/articles/10.1186/s13756-019-0666-4. Accessed February 6, 2022.
27. Boyce JM. Current issues in hand hygiene: a state of the science review. *Am J Infect Control*. 2019;47:a46–a52.
28. Gould DJ, Moralejo D, Drey N, et al. Interventions to improve hand hygiene compliance in patient care (Review). *Cochrane Library*. 2017. www.ncbi.nlm.nih.gov/pmc/articles/PMC6483670/. Accessed April 7, 2022.
29. Alshehari AA, Park S, Rashid H. Strategies to improve hand hygiene compliance among healthcare workers in adult intensive care units: a mini systematic review. *J Hosp Infect*. 2018;100:152–158.
30. Boyce JM. Impact of an automated hand hygiene monitoring system and additional promotional activities on hand hygiene performance rates and healthcare-associated infections. *Infect Control Hosp Epidemiol*. 2019;40:741–747.
31. Wang C, Jiang W, Yang K, et al. A systematic review of electronic monitoring systems for hand hygiene. *J Med Internet Research*. 2021. www.jmir.org/2021/11/e27880/. Accessed April 7, 2022.
32. Lorenzi N. *Automated Hand-Hygiene System Evolution Continues: Data collection Expands While COVID-19 Presents New Challenges*. ASHE Health Facilities Management; 2021. https://www.hfmmagazine.com/articles/4112-automated-hand-hygiene-system-evolution-continues. Accessed February 6, 2022.
33. Leapfrog Hospital Group. Fact Sheet: Leapfrog Hospital Survey Hand Hygiene. https://ratings.leapfroggroup.org/sites/default/files/inline-files/2021%20Hand%20Hygiene%20Fact%20Sheet_0.pdf. Accessed February 6, 2022.
34. Donskey CJ. Does improving surface cleaning and disinfection reduce health care-associated infections? *Am J Infect Control*. 2013;41:S12–S19.
35. Stiefel U, Cadnum JL, Eckstein BC, et al. Contamination of hands with methicillin-resistant *Staphylococcus aureus* after contact with the skin of colonized patients. *Infect Control Hosp Epidemiol*. 2011;32:185–187.
36. Suleyman G, Alangaden G, Bardossy AC. The role of environmental contamination in the transmission of nosocomial pathogens and healthcare-associated infections. *Curr Infections Dis Rep*. 2018;20:11–12.
37. Dancer SJ. The role of environmental cleaning in the control of hospital acquired infection. *J Hosp Infect*. 2009;73:378–385.
38. Boyce JM. Environmental contamination makes an important contribution to hospital infection. *J Hosp Infect*. 2007;65:50–54.
39. Weber DJ, Rutala WA, Miller MB, et al. Role of hospital surfaces in the transmission of emerging health care-associated pathogens: norovirus, *Clostridium difficile*, and *Acinetobacter* species. *Am J Infect Control*. 2010;38:S25–S33.
40. Kramer A, Schwebke I, Kampf G. How long do nosocomial pathogens persist on inanimate surfaces? A systematic review. *BMC Infect Dis*. 2006. https://bmcinfectdis.biomedcentral.com/articles/10.1186/1471-2334-6-130. Accessed February 6, 2022.
41. Chen LF, Knelson LP, Gergen MF, et al. A prospective study of transmission of multidrug-resistant organisms (MDROs) between environmental sites and hospitalized patients – the TransFER study. *Infect Control Hosp Epidemiol*. 2018;40:47–52.

42. Cohen B, Liu J, Cohen AR, et al. Association between healthcare-associated infection and exposure to hospital roommates and previous bed occupants with the same organism. *Infect Control Hosp Epidemiol*. 2018;39:541–546.
43. Carling PC, Parry MF, Von Beheren SM. Healthcare Environmental Hygiene Study Group. Identifying opportunities to enhance environmental cleaning in 23 acute care hospitals. *Infect Control Hosp Epidemiol*. 2008;29:1–7.
44. Carling PC, von Bheren S, Kim P, et al. Intensive care unit environmental cleaning: an evaluation in sixteen hospitals using a novel assessment tool. *J Hosp Infect*. 2008;68:39–44.
45. Weber DJ, Rutala WA, Anderson DJ, et al. Effectiveness of ultraviolet devices and hydrogen peroxide systems for terminal room decontamination: focus on clinical trials. *Am J Infect Control*. 2016;44:77–84.
46. Snyder GM, Holyoak AD, Leary KE, et al. Effectiveness of visual inspection compared with non-microbiologic methods to determine the thoroughness of post-discharge cleaning. *Antimicrob Resist Infect Control*. 2013;2:26.
47. Huslage K, Rutala WA, Gergen MF, et al. Microbial assessment of high, medium, and low-touch hospital room surfaces. *Infect Control Hosp Epidemiol*. 2013;34:211–212.
48. Anderson DJ, Chen LF, Weber DJ, et al. Enhanced terminal room disinfection and acquisition and infection caused by multidrug-resistant organisms and *Clostridium difficile* (the Benefits of Enhanced Terminal Room Disinfection study): a cluster-randomized, multicenter, crossover study. *Lancet*. 2017;389:805–814.
49. Rutala WA, Weber DJ. Disinfectants used for environmental disinfection and new room decontamination technology. *Am J Infect Control*. 2013;41:526–541.
50. Boyce JM. Modern technologies for improving cleaning and disinfection of environmental surfaces in hospitals. *Antimicrob Resistance Infect Control*. 2016. https://aricjournal.biomedcentral.com/articles/10.1186/s13756-016-0111-x . Accessed February 6, 2022.
51. Falagas ME, Thomaidis PC, Kotsantis IK, et al. Airborne hydrogen peroxide for disinfection of the hospital environment and infection control: a systematic review. *J Hosp Infect*. 2011;78:171–177.
52. Otter JA, Puchowicz M, Ryan D, et al. Feasibility of routinely using hydrogen peroxide vapor to decontaminate rooms in a busy United States hospital. *Infect Control Hosp Epidemiol*. 2009;30:574–577.
53. Marra AR, Schweizer ML, Edmond MB. No-touch disinfection methods to decrease multidrug-resistant organism infections: a systematic review and meta-analysis. *Infect Control Hosp Epidemiol*. 2018;39:20–31.
54. Cadnum JL, Jencson AL, Livingston SH, et al. Evaluation of an electrostatic spray disinfectant technology for rapid decontamination of portable equipment and large open areas in the era of SARS-CoV-2. *Am J Infect Control*. 2020;48:951–954.
55. Murrell L, Hamilton EK, Johnson HB, et al. Influence of a visible light continuous environmental disinfection system on microbial contamination and surgical site infections in orthopedic operating room. *Am J Infect Control*. 2019;47:804–810.
56. Inman T. Evaluation of a continuous decontamination technology in an intensive care unit. Center for Disease Control and Prevention. Decennial 2020. *Infect Control Hosp Epidemiol*. 2020. https://www.cambridge.org/core/services/aop-cambridge-core/content/view/81F3DFF7057C132BC4A13C7E5AACBAB5/S0899823X20012015a.pdf/evaluation-of-a-continuous-decontamination-technology-in-an-intensive-care-unit.pdf. Accessed February 6, 2022.
57. Sanguinet J, Edmiston C. Evaluation of dry hydrogen peroxide in reducing microbial bioburden in a healthcare facility. *Am J Infect Control*. 2021;49:985–990.
58. Naghavi M. Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. *Lancet*. 2022. https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(21)02724-0/fulltext. Accessed February 6, 2022.
59. Centers for Disease Control and Prevention. CDC Launces Two Global Networks, Awards $22 Million to Combat Antimicrobial Resistance and Infectious Diseases. CDC Newsroom. https://www.cdc.gov/media/releases/2021/p1207-global-action-healthcare-network.html. Accessed February 6, 2022.
60. Clinical and Laboratory Standards Institute. *How Using CLSI's M100 Helps Fight Against Antimicrobial Resistance*. Clinical and Laboratory Standards Institute; 2020. https://clsi.org/about/blog/how-using-clsi-s-m100-helps-the-fight-against-antimicrobial-resistance/. Accessed February 6, 2022.
61. Humphries RM, Hindler JA, Epson E, et al. Carbapenem-resistant *Enterobacteriaceae* detection practices in California: what are we missing? *Clin Infect Dis*. 2018;66:1061–1067.
62. World Health Organization. Global Priority List of Antibiotic-Resistant Bacteria to Guide Research, Discovery, and Development of New Antibiotics. World Health Organization. https://www.who.int/medicines/publications/WHO-PPL-Short_Summary_25Feb-ET_NM_WHO.pdf. Accessed February 6, 2022.
63. Centers for Disease Control and Prevention. Antibiotic Resistance & Patient Safety Portal. Centers for Disease Control and Prevention. https://arpsp.cdc.gov/resources/AR-PhenotypeDefinitions.pdf. Accessed February 6, 2022.
64. Centers for Disease Control and Prevention. Antibiotic Resistance Threats in the United States 2019. Centers for Disease Control and Prevention. https://www.cdc.gov/drugresistance/pdf/threats-report/2019-ar-threats-report-508.pdf. Accessed February 6, 2022.
65. National Healthcare Safety Network. Multidrug-Resistant Organism & *Clostridioides difficile* Infection (MDRO/CDI) Module. National Healthcare Safety Network. https://www.cdc.gov/nhsn/pdfs/pscmanual/12pscmdro_cdadcurrent.pdf. Accessed February 6, 2022.
66. Centers for Disease Control and Prevention. Carbapenem-Resistant Enterobacterales (CRE). Centers for Disease Control and Prevention. https://www.cdc.gov/hai/organisms/cre/index.html. Accessed February 6, 2022.
67. Centers for Disease Control and Prevention. Inter-Facility Infection Control Transfer Form for States Establishing HAI Prevention Collaboratives. Centers for Disease Control and Prevention. https://www.cdc.gov/hai/pdfs/toolkits/Interfacility-IC-Transfer-Form-508.pdf. Accessed April 5, 2022.
68. Centers for Disease Control and Prevention. Containing Multi-Drug-Resistant Organisms in a Long-Term Acute-Care Hospital. Florida Department of Health in Orange County. https://www.cdc.gov/publichealthgateway/field-notes/2019/fl-mdro.html. Accessed February 6, 2022.
69. Edmiston CE, Garcia R, Barnden M, et al. Rapid diagnostics for bloodstream infections: a primer for infection preventionists. *Am J Infect Control*. 2018;46:1060–1068.
70. Climo MW, Yokee DS, Warren DK, et al. Effect of daily chlorhexidine bathing on hospital-acquired infection. *N Engl J Med*. 2013;368:533–542.
71. Milstone AM, Elward A, Song X, et al. Daily chlorhexidine bathing to reduce bacteremia in critically ill children: a multicentre, cluster-randomized, crossover trial. *Lancet*. 2013;381:1099–1106.
72. Huang SS, Septimus E, Kleinman K, et al. Targeted versus universal decolonization to prevent ICU infection. *N Engl J Med*. 2013;368:2255–2265.
73. Marschall J, Mermel LA, Fakih M, et al. Strategies to prevent central line associated bloodstream infections in acute care hospitals: 2014 update. *Infect Control Hosp Epidemiol*. 2014;34:753–771.
74. Huang SS, Septimus E, Kleinman K, et al. Chlorhexidine versus routine bathing to prevent multidrug-resistant organisms and all-cause bloodstream infections in general medical and surgical units (ABATE Infection trial): a cluster-randomized trial. *Lancet*. 2019;393:1205–1215.
75. Kourtis AP, Hatfield K, Baggs J, et al. Vital Signs: epidemiology and recent trends in methicillin-resistant and in methicillin-susceptible *Staphylococcus aureus* bloodstream infections - United States. *MMWR Morb Mortal Wkly Rep*. 2019;68:214–219.
76. Schweizer ML, Chiang H-Y, Septimus E, et al. Association of a bundled intervention with surgical site infections among patients undergoing cardiac, hip, or knee surgery. *JAMA*. 2015;313:2162–2171.
77. Slawinski G, Lewicks E, Kempa M, et al. Infections of cardiac implantable electronic devices. Epidemiology, classification, treatment, and prognosis. *Adv Clin Exp Med*. 2019;28:263–270.
78. Sandoe JA, Barlow G, Chambers JB, et al. Guidelines for the diagnosis, prevention and management of implantable cardiac electronic device infection. *J Antimicrob Chem*. 2015;70:325–359.
79. Didier L. Povidone iodine: properties, mechanisms of action, and role in infection control and *S. aureus* decolonization. *Antimicrobial Agents Chem*. 2020;64:1–13.
80. Mullen A, Wieland HJ, Wieser ES, et al. Perioperative participation of orthopedic patients and surgical staff in a nasal decolonization intervention to reduce *Staphylococcus* spp surgical site infections. *Am J Infect Control*. 2017;45:554–556.
81. Septimus EJ, Schweizer ML. Decolonization in prevention of health care-associated infections. *Clin Microbiol Rev*. 2016;29:201–222.
82. Siegel JD, Rhinehart E, Jackson M, Chiarello L, Healthcare Infection Control Practices Advisory Committee. Management of multidrug-resistant organisms in health care settings, 2006. *Am J Infect Control*. 2007;35(10 Suppl 2):S165–S193.
83. Marra AR, Edmond MB, Schweizer ML, et al. Discontinuing contact precautions for multidrug-resistant organisms: a systematic literature review and meta-analysis. *Am J Infect Control*. 2018;46:333–340.
84. Nair R, Perencevich EN, Goto M, et al. Patient care experience with utilization of isolation precautions: systematic literature review and meta-analysis. *Clin Microbiol Infect*. 2020;26:684–695.
85. Martin EM, Bryant B, Grogan TR, et al. Noninfectious hospital adverse events decline after elimination of contact precautions for MRSA and VRE. *Infect Control Hosp Epidemiol*. 2018;39:788–796.
86. Gandra S, Barysauskas CM, Mack DA, et al. Impact of contact precautions on falls, pressure ulcers and transmission of MRSA and VRE in hospitalized patients. *J Hosp Infect*. 2014;88:170–176.
87. Knelson LP, Williams DA, Gergen MF, et al. A comparison of environmental contamination by patients infected or colonized with methicillin-resistant *Staphylococcus aureus* or vancomycin-resistant *enterococci*: a multicenter study. *Infect Control Hosp Epidemiol*. 2014;35:872–875.
88. Chang S, Sethi AK, Eckstein BC, et al. Skin and environmental contamination with Methicillin-Resistant *Staphylococcus aureus* among carriers identified clinically versus through active surveillance. *Clin Infect Dis*. 2009;48:1423–1428.
89. Banach D, Bearman G, Barnden M, et al. Duration of contact precautions for acute-care settings. *Infect Control Hosp Epidemiol*. 2018;39:127–144.
90. Thompson P, Teter J, Atrubin K. Incidence of health care-associated extended-spectrum β-lactamase-positive patients before and after discontinuation of contact precautions. *Am J Infect Control*. 2020;48:52–55.
91. Ben-David D, Masarwa S, Fallach N, et al. Israel Long-term Care Facility (LTCF) CRE Working Group. National Policy for Carbapenem-Resistant Enterobacteriaceae (CRE) clearance and discontinuation of contact precautions for CRE carriers in post-acute care hospitals in israel: impact on isolation-days and new acquisitions. *Clin Infect Dis*. 2021;72:829–835.
92. Bartsch SM, Wong KF, Mueller LE, et al. Modeling interventions to reduce the spread of multidrug-resistant organisms between health care facilities in a region. *JAMA Netw Open*. 2021. https://jamanetwork.com/journals/jamanetworkopen/fullarticle/2782668. Accessed February 6, 2022.
93. Centers for Disease Control and Prevention. Healthcare Infection Control Practices Committee. *Record of the Proceedings*. 2021. https://www.cdc.gov/hicpac/pdf/2021-August-HICPAC-Summary-508.pdf. Accessed February 6, 2022.
94. Septimus EJ. Antimicrobial resistance. An antimicrobial/diagnostic stewardship and infection prevention approach. *Med Clin N Am*. 2018;102:819–829.

95. Madden GR, Weinstein RA, Sifri CD. Diagnostic stewardship for healthcare-associated infections: opportunities and challenges to safely reduce test use. *Infect Control Hosp Epidemiol*. 2018;39:214–218.
96. Jones K, Sibai J, Battjes R, Fakih MG. How and when nurses collect urine cultures on catheterized patients: a survey of 5 hospitals. *Am J Infect Control*. 2016;44:173–176.
97. Garcia RA, Spitzer ED, Beaudry J, et al. Multidisciplinary team review of best practices for collection and handling of blood cultures to determine effective interventions for increasing the yield of true-positive bacteremias, reducing contamination, and eliminating false-positive central line-associated bloodstream infections. *Am J Infect Control*. 2015;43:1222–1237.
98. Curren EJ, Lutgring JD, Kabbani S, et al. Advancing diagnostic stewardship for healthcare-associated infections, antibiotic resistance, and sepsis. *Clin Infect Dis*. 2021. https://pubmed.ncbi.nlm.nih.gov/34346494/. Accessed February 6, 2022.
99. World Health Organization. *Diagnostic Stewardship. A Guide to Implementation in Antimicrobial Resistance Surveillance Sites*. 2016. https://apps.who.int/iris/handle/10665/251553. Accessed February 6, 2022.
100. Morency-Potvin P, Schwartz DN, Weinstein RA. Antimicrobial Stewardship: how the microbiology laboratory can right the ship. *Clin Micro Reviews*. 2017;30:381–407.
101. Monsees EA, Tamma PD, Cosgrove SE, et al. Integrating bedside nurses into antibiotic stewardship: a practical approach. *Infect Control Hosp Epidemiol*. 2019;40:579–584.
102. Fakih M. Principles of highly reliable care: improving the culture of culturing—avoiding unnecessary urine cultures in catheterized patients. Ascension Health. *Clin Excellence*. 2014:1–20. February.
103. Dik JH, Poelman R, Friedrich AW, et al. Integrated stewardship model comprising antimicrobial, infection prevention and diagnostic stewardship (AID Stewardship). *J Clin Micro*. 2017;55:3306–3307.
104. Messacar K, Parker SK, Todd JK, Dominguez SR. Implementation of rapid molecular infectious disease diagnostics: the role of diagnostic and antimicrobial stewardship. *J Clin Micro*. 2017;55:715–723.
105. Centers for Disease Control and Prevention. *Urine Culture Stewardship in Hospitalized Patients*. Centers for Disease Control and Prevention; 2019. https://www.cdc.gov/hai/prevent/cauti/index.html. Accessed February 6, 2022.
106. Choi EC, Chia YH, Koh YQ, et al. Appropriateness of blood culture: a comparison of practices between the emergency department and general ward. *Infect Dis Health*. 2019;24:49–55.
107. Chen AI, Bilker WB, Hamilton KW, et al. Blood culture utilization at an academic hospital: addressing a gap in benchmarking. *Infect Control Hosp Epidemiol*. 2018;39:1353–1359.
108. Munigala S, Rojek R, Wood H, et al. Effect of changing urine testing orderables and clinician order sets on inpatient urine culture testing: analysis from a large academic medical center. *Infect Control Hosp Epidemiol*. 2019;40:281–286.
109. Kuper KM, Hamilton KW. Collaborative antimicrobial stewardship: working with information technology. *Infect Dis Clin N Am*. 2020;34:31–49.
110. Zimmerman FS, Assosu MV, Zevin S, Weiner-Well Y. Reducing blood culture contamination using an initial specimen diversion device. *Am J Infect Control*. 2019;47:822–826.
111. White DR, Hamilton KW, Pegues DA, et al. The impact of a computerized clinical decision support tool on inappropriate *Clostridium difficile* testing. *Infect Control Hosp Epidemiol*. 2017;38:1204–1208.
112. Dunn AN, Radakovich N, Ancker JS, et al. The impact of clinical decision support alerts on *Clostridioides difficile* testing: a systematic review. *Clin Infect Dis*. 2021:987–994.
113. Lee HS, Plechot K, Gohil S, Le J. *Clostridium difficile*: diagnosis and the consequence of over diagnosis. *Infect Dis Ther*. 2021;10:687–697.
114. Muto C, Patrick A, Hess O, Rittmann BJ, et al. *Accuracy of the NHSN Central-Line –Associated Bloodstream Infections (CLABSIs) Definition: The Experience of Two Geographically Proximal Hospitals*. Decennial; 2020. https://www.cambridge.org/core/services/aop-cambridgecore/content/view/8237F43447CEB831348-F3AB0D163967C/S0899823X20011319a.pdf/accuracy-of-the-nhsn-central-line-associated-bloodstream-infections-clabsis-definition-the-experience-of-two-geographically-proximal-hospitals.pdf. Accessed February 6, 2022.
115. Beaudry J, ScottoDiMaso K. Reducing central line-associated bloodstream infections on a hematologic malignancy and stem cell transplant unit. *Clin J Oncology Nur*. 2020;24:148–153.
116. Holinga G. *In vitro* antimicrobial effects of chlorhexidine diacetate versus chlorhexidine free base dressings. *J Wound Care*. 2020;29:522–528.
117. O'Horo JC. Arterial catheters as a source of bloodstream infection: a systematic review and meta-analysis. *Crit Care Med*. 2014;42:1334–1339.
118. Shingarev R. Natural history of tunneled dialysis catheters placed for hemodialysis initiation. *J Vasc Interv Radiol*. 2013;24:1289–1294.
119. Chopra V. Variation in use and outcomes related to midline catheters: results from a multicentre pilot study. *BMI Qual Saf*. 2019;28:714–720.
120. Kovacs CS. Hospital-acquired *Staphylococcus aureus* primary bloodstream infection: a comparison of events that do and do not meet the central line-associated blood stream infection definition. *Am J Infect Control*. 2016;44:1252–1255.
121. Keller S, Williams D, Rock C, et al. A new frontier: central line-associated bloodstream surveillance in home infusion therapy. *Am J Infect Control*. 2019;46:1419–1421.
122. Fakih M, Bufalino A, Strum L, et al. Coronavirus disease 2019 (COVID 19) pandemic, central line-associated bloodstream infection (CLABSI), and catheter-associated urinary tract infection (CAUTI): the urgent need to refocus on hardwiring prevention efforts. *Infect Control Hosp Epidemiol*. 2022;43:26–31.
123. Ji W, McKenna C, Ochoa A, et al. Development and assessment of objective surveillance definitions for nonventilator hospital-acquired pneumonia. *JAMA Netw Open*. 2019. https://pubmed.ncbi.nlm.nih.gov/31626321/. Accessed February 6, 2022.
124. Munro SC, Baker D, Giuliano KK, et al. Nonventilator hospital-acquired pneumonia: a call to action. *Infect Control Hosp Epidemiol*. 2021;42:991–996.
125. Giuliano KK, Baker D. Sepsis in the context of nonventilator hospital-acquired pneumonia. *Am J Crit Care*. 2020;29:9–14.
126. Carey E, Blankenhorn R, Chen P, Munro S. Non-ventilator associated hospital acquired pneumonia incidence and health outcomes among U.S. veterans from 2016-2020. *Am J Infect Control*. 2021;50:116–119.
127. Joint Commission Safety Briefing Issue 61. *Preventing Non-ventilator Hospital-Acquired Pneumonia*. The Joint Commission; 2021. https://www.jointcommission.org/-/media/tjc/newsletters/quick-safety-61-nvha-pneumonia-final-9-3-21.pdf. Accessed February 6, 2022.
128. Giuliano KK, Penoyer D, Middleton A, Baker D. Original Research: oral care as prevention for nonventilator hospital-acquired pneumonia: a four-unit cluster randomized study. *Am J Nurs*. 2021;121:24–33.
129. Munro S, Haile-Mariam A, Greenwell C, et al. Implementation and dissemination of a Department of Veterans Affairs oral care initiative to prevent hospital acquired pneumonia among non-ventilated patients. *Nurs Admin Q*. 2018;42:363–372.
130. Munro S, Phillips T, Hasselbeck R, et al. Implementing oral care as a nursing intervention to reduce hospital-acquired pneumonia across the United States department of veterans affairs healthcare system. *Comput Inform Nurs*. 2022;40:35–43.
131. *Pneumonia (Ventilator-associated [VAP] and Non-ventilator associated Pneumonia [PNEU]) Event*. Centers for Disease Control and Prevention; 2021. https://www.cdc.gov/nhsn/pdfs/pscmanual/6pscvapcurrent.pdf. Accessed February 6, 2022.
132. *Ventilator-Associated Event (VAE)*. Centers for Disease Control and Prevention; 2021. https://www.cdc.gov/nhsn/pdfs/pscmanual/10-vae_final.pdf. Accessed February 6, 2022.
133. Spalding MC, Cripps MW, Minshall CT. Ventilator-associated pneumonia: new definitions. *Critical Care Clinics*. 2017;33:277–292.
134. Klompas M. Ventilator-associated events: what they are and what they are not. *Respir Care*. 2019;64:953–961.
135. Fan Y, Gao F, Wu Y, et al. Does ventilator associated event surveillance detect ventilator-associated pneumonia in intensive care units? A systematic review and meta-analysis. *Crit Care*. 2016;20:1–13.
136. Zosa BM, Golob JF, Conrad-Schnetz KJ, et al. Current pneumonia surveillance methodology: similar underestimation in trauma and surgical patients in the intensive care unit. *Surg Infect*. 2017;18:558–562.
137. Lee TB, Montgomery OG, Marx J, et al. Recommended practices for surveillance: Association for Professionals in Infection Control and Epidemiology (APIC), Inc. *Am J Infect Control*. 2007;35:427–440.
138. Nicolle LE, Gupta K, Bradley SF, et al. Clinical Practice Guideline for the Management of Asymptomatic Bacteriuria: 2019 Update by the Infectious Diseases Society of America. *Clin Infect Dis*. 2019;68:e83–e110.
139. Horstman MJ, Spiegelman A, Naik AD, Trautner BW. National patterns of urine testing during inpatient admission. *Clin Infect Dis*. 2017;65:1199–1205.
140. Ashraf MS, Gaur S, Bushen OY, et al. Diagnosis, treatment, and prevention of urinary tract infections in post-acute and long-term care settings: a consensus statement from AMDA's infection advisory subcommittee. *J Am Med Dir Assoc*. 2020;21:12–24.
141. Hooton TM, Bradley SF, Cardenas DD, et al. Diagnosis, prevention, and treatment of catheter-associated urinary tract infection in adults: 2009 International Clinical Practice Guidelines from the Infectious Diseases Society of America. *Clin Infect Dis*. 2010;50:625–663.
142. Fakih MG, Advani SD, Vaughn VM. Diagnosis of urinary tract infections: need for a reflective rather than reflexive approach. *Infect Control Hosp Epidemiol*. 2019;40:834–835.
143. Garcia R, Spitzer E. Promoting appropriate urine culture management to improve health care outcomes and the accuracy of catheter-associated urinary tract infections. *Am J Infect Control*. 2017;40:1143–1153.
144. Humphries RM, Dien Bard J. Point-counterpoint: reflex cultures reduce laboratory workload and improve antimicrobial stewardship in patients suspected of having urinary tract infections. *J Clin Microbiol*. 2016;54:254–258.
145. Advani SD, Fakih MG. The evolution of catheter-associated urinary tract infection (CAUTI): is it time for more inclusive metrics? *Infect Control Hosp Epidemiol*. 2019;40:681–685.
146. Edmiston CE, Spencer M, Lewis BD, et al. Reducing the risk of surgical site infections: did we really think that SCIP would lead us to the promise land? *Surg Infection*. 2011;12:169–177.
147. Leaper DJ, Edmiston CE. World Health Organization: global guidelines for the prevention of surgical site infection. *J Hosp Infect*. 2017;95:135–136.
148. Edmiston CE, Krepel C, Spencer M, et al. Evidence for preadmission showering regimen to achieve maximal antiseptic skin surface concentrations of chlorhexidine gluconate, 4% in surgical patients. *JAMA Surg*. 2015;150:1027–1032.
149. Association of PeriOperative Registered Nurses (AORN). *Guidelines for Perioperative Practice*. AORN; 2021.
150. Bratzler DW, Dellinger EP, Olsen KM, et al. Clinical Practice guidelines for antimicrobial prophylaxis in surgery. *Surg Infection*. 2013;13:73–156.

151. Septimus EJ. Nasal decolonization: what antimicrobials are most effective prior to surgery? *Am J Infect Control*. 2019;47S:A53–A57.
152. Kurz A, Kopyeva T, Suliman I, et al. Supplemental oxygen and surgical site infections: an alternating intervention-controlled study. *Br J Anesthesia*. 2018;120:117–126.
153. Connelly L, Cramer E, DeMott Q, et al. The optimal time and method for surgical prewarming: a comprehensive review of the literature. *J Perianesth Nurs*. 2017;32:199–209.
154. Garg R, Schuman B, Bader A, et al. Effect of preoperative diabetes management on glycemic control and clinical outcomes after elective surgery. *Ann Surg*. 2018;267:858–862.
155. Ahmed I, Boulton AJ, Rizvi S, et al. The use of triclosan-coated sutures to prevent surgical site infections: a systematic review and meta-analysis of the literature. *BMJ Open*. 2019. https://bmjopen.bmj.com/content/9/9/e029727.long. Accessed February 6, 2022.
156. Leaper DJ, Edmiston CE, Holy CE. Meta-analysis of the potential economic impact following introduction of absorbable antimicrobial sutures. *Br J Surg*. 2017;104:e134–e144.
157. Singh A, Bartsch SM, Muder RR, Lee BY. An economic model: value of antimicrobial-coated sutures to society, hospitals, and third-party payers in preventing abdominal surgical site infections. *Infect Control Hospital Epidemiol*. 2014;35:1013–1020.
158. National Institue of Allergy and Infectious Diseases (NIAID) Emerging Infectious Diseases/Pathogens. https://www.niaid.nih.gov/research/emerging-infectious-diseases-pathogens. Accessed February 6, 2022.
159. Centers for Disease Control and Prevention. History of Ebola Virus Disease (EVD) Outbreaks. https://www.cdc.gov/vhf/ebola/history/chronology.html?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Fvhf%2Febola%2Foutbreaks%2Fhistory%2Fchronology.html. Accessed February 6, 2022.
160. Abouleish MYZ. Indoor air quality and COVID-19. *Public Health*. 2021;191:1–2.
161. Palmore TN, Smith BA. *COVID-19: General Approach to Infection Prevention in the Health Care Setting*. UpToDate; 2021. UpToDate; https://www.uptodate.com/contents/covid-19-general-approach-to-infection-prevention-in-the-health-care-setting. Accessed February 6, 2022.
162. World Health Organization. Infection Prevention and Control During Health Care When Coronavirus Disease (COVID-19) is Suspected or Confirmed. https://www.who.int/publications/i/item/WHO-2019-nCoV-IPC-2021.1. Accessed February 6, 2022.
163. Wei EK, Long T, Katz MH. Nine lessons learned From the COVID-19 pandemic for improving hospital care and health care delivery. *JAMA Intern Med*. 2021;181:1161–1163.
164. Seresirikachorn K, Phoophiboon V, Chobarporn T, et al. Decontamination and reuse of surgical masks and N95 filtering facepiece respirators during the COVID-19 pandemic: a systematic review. *Infect Control Hosp Epidemiol*. 2021;42:25–30.
165. Boškoski I, Gallo C, Wallace MB, Costamagna G. COVID-19 pandemic and personal protective equipment shortage: protective efficacy comparing masks and scientific methods for respirator reuse. *Gastrointest Endosc*. 2020;92:519–523.
166. Zulauf KE, Green AB, Nguyen Ba AN, et al. Microwave-generated steam decontamination of N95 respirators utilizing universally accessible materials. *mBio*. 2020;11. https://annb-lab.github.io/assets/publications/Zulauf_2020_mBio-2020-Zulauf-e00997-20.full.pdf. Accessed February 6, 2022.
167. Ozog D, Parks-Miller A, Levesque M, et al. The importance of fit testing in decontamination of N95 respirators: a cautionary note. *J Am Acad Dermatol*. 2020;83:672–674.
168. Barnett ML, Mehrotra A, Landon BE. COVID-19 and the upcoming financial crisis in health care. *NEJM Catalyst*. 2020. https://catalyst.nejm.org/doi/full/10.1056/CAT.20.0153. Accessed April 7, 2022.
169. American Hospital Association. Kaufman Hall & Associates. Financial Effects of COVID-19: Hospital Outlook for the Remainder of 2021. www.aha.org/guidesreports/2021-09-21-financial-effects-covid-19-hospital-outlook-remainder-2021#:~:text=Kaufman%20Hall%20projects%20hospitals%20nationwide,Act%20funding%20from%20last%20year. Accessed April 7, 2022.
170. McAlearney AS, Gaughan AA, DePuccio MJ, et al. Management practices for leaders to promote infection prevention: lessons from a qualitative study. *Am J Infect Control*. 2021;49:536–541.