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New Technologies and Advances in Infections Prevention (AR Marra, Section Editor)

New Interventions Targeting Healthcare-Associated Infections

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Abstract

Purpose of review Healthcare-associated infections (HCAIs) are still a major cause of patient morbidity and mortality nowadays and there are evidences that these infections are highly preventable. Although many efforts have been made to prevent them, we live with a global burden of HCAIs and low- and middle-income countries reported HCAIs rates higher than in high-income countries accompanied by the problem of multidrug resistant microorganisms.
Recent findings Basic measures for infection control and prevention must be put into practice and new techniques and methodologies have to be incorporated into HCAI control programs. The purpose of this review is discuss new interventions targeting HCAIs such as the use of practice bundles, behavioral change strategies, public reporting of infection rates, environmental cleaning, hand hygiene, and antimicrobial stewardship programs.
Summary We emphasize that all preventive measures require adherence by healthcare workers that depends on behavioral changes and reinforce that classical subjects as hand hygiene, environmental cleaning, and prudent use of antimicrobials need to be rethinking on the set of new technologies using electronic media for alerts, consultations, and audits.

Introduction

Healthcare-associated infections are a major cause of patient morbidity and mortality. Fortunately for patients and the healthcare system, there is increasing interest in this field and the arise recognition that many of these

infections are highly preventable. We explore interventions targeting healthcare-associated infections including the use of practice bundles, behavioral change strategies, public reporting of infection rates, environmental cleaning, hand hygiene, and antimicrobial stewardship programs. We pointed that behavioral change strategies are the key point to improve adherence to organizational policies and infection prevention and control interventions.

The burden of healthcare-associated infections (HCAI)

Healthcare-associated infections (HCAI) are the most frequent adverse outcome in healthcare settings worldwide, affect hundreds of millions of people worldwide, and are a major global challenge for patient safety.

However, the global burden of HCAI remains unknown because of the difficulty to gather reliable data. In many settings, from hospitals to outpatient's clinics and long-term care, HCAI appear to be a hidden, cross-cutting problem that no institution or country can claim to have solved yet. HCAI surveillance is complex and requires the use of standardized criteria, availability of diagnostic tools, and expertise to interpret the results. Surveillance systems for HCAI are available in several high-income countries; however, they are not feasible in most low- and middle-income countries [1].

The World Health Organization (WHO) conducted a systematic review of literature on endemic HCAI from 1995 to 2010 in high- and low- and middle-income countries. This review observed that there are robust data compiled in Europe and the USA by European Center for Disease Prevention and Control (ECDC) and CDC; however, there is a lack of data in developing countries. The fact is that low- and middle-income countries reported HCAI rates higher than in high-income countries as expected [2]. The rates observed in this review are shown in Table 1.

HCAI can lead to prolonged hospital stay, long-term disability, increased resistance of microorganisms to antimicrobials, massive additional costs for health systems, high costs for patients and their family, and unnecessary deaths [3].

Table 1. Comparison of rates of HCAI in high- and low- and middle-income countries [2]

Rates	High-income countries	Low- and middle-income countries
Surgical site infections (%)	1.2–5.2	1.2–23.6
Pooled cumulative incidence—ICU (1000 patient-days)	17	42.7
CR-BSI (1000 central lines days)	3.5	12.2
CR-UTI (1000 urinary catheter-days)	4.1	8.8
VAP (1000 ventilators days)	7.9	23.9

ICU intensive care unit, *CR-BSI* catheter-related bloodstream infection, *CR-UTI* catheter-related urinary tract infection, *VAP* ventilator-associated pneumonia

From 2010 to the present, the burden of multidrug resistant pathogens has been increased. Antimicrobial resistance is occurring everywhere in the world, compromising our ability to treat infectious diseases.

Both World Health Organization (WHO) and Center for Diseases Control and Prevention (CDC) have call attention to this problem and tried to integrate programs to reduce HCAI by assisting with the assessment, planning, and implementation of infection prevention and control policies, including timely actions at national and institutional levels [4•,5].

However, we are still far to solve this question; on the other hand, there is strong evidence that HCAI can be prevented. Nonetheless, it is imperative that basic measures for infection control and prevention must be put into practice such as the implementation of standard and isolation precautions, environmental cleaning, water and sanitation in health-care settings, sterilization and disinfection procedures, and specific measures for injection safety [6].

In this scenario, new techniques and methodologies have been incorporated into HCAI control programs and will be discussed in this paper.

The use of practice bundles

Care bundles are a set of three to five evidence-informed practices performed collectively and reliably to improve the quality of patient care. Care bundles are used widely across healthcare settings with the aim to preventing and managing different health conditions [7].

The impact of bundle on reduction of central line-associated bloodstream infections (CLABSI) and ventilator-associated pneumonia (VAP) has been greatly studied in the literature.

A search in PubMed database by entering keywords such as "care bundles and central line-associated infections" found 79 articles in different scenarios (intensive care units for adults, pediatrics, and neonates). The majority of studies observed favorable results related to bundle implementation. Two systematic reviews highlighted the benefits of bundles and one study showed maintenance of zero rate for 2 years after the implementation of the bundle.

The first systematic review analyzed 96 studies and showed that the median of CLABSI incidence were 5.7 per 1000 catheter-days on adult ICUs, 5.9 per 1000 catheter-days on pediatric ICUs, and 8.4 per 1000 catheter-days on neonatal ICUs. In this review, the incidence of infections decreased significantly from median 6.4 per 1000 catheter-days to 2.5 per 1000 catheter-days after implementation of bundles (IRR 0.44, 95% CI 0.39–0.50, $p < 0 \cdot 0001$; $I^2 = 89\%$) [8].

The other systematic review included 19 studies. A variety of interventions was used for the prevention or reduction of central venous line associated bloodstream infections. These interventions included dressings, closed infusion systems, aseptic skin preparation, central venous line bundles, quality improvement initiatives, education, and an extra staff in the intensive care unit [9•].

In another study, the care bundle was introduced in 2009 and included a previously established line insertion procedure and a novel line maintenance procedure, daily 2% chlorhexidine body wash, daily ICU central line review, and liaison nurse follow-up of central lines. The average CLABSI rate fell from 2.2/1000 central line days (peak of 5.2/1000 central line days) during the pre-

intervention period to 0.5/1000 central line days (0/1000 central line days from July 2012 to July 2014) during the post-intervention period [10].

Regarding VAP, a search in PubMed database by entering keywords "care bundles and ventilator-associated pneumonia" found 115 articles. Many centers continue to report dramatic decreases in VAP rates after implementing ventilator bundles. Interpreting these reports is complicated by the subjectivity and lack of specificity of VAP definitions. More robust data suggest VAP rates may not have meaningfully changed over the past decade. If so, this compels us to re-examine and revise the prevention bundles that we have been using to prevent VAP.

Recent studies suggest that most hospitals' ventilator bundles include a mix of helpful elements. Spontaneous awakening trials, spontaneous breathing trials, head-of-bed elevation, and thrombosis prophylaxis appear beneficial. Selective digestive decontamination by contrast appears to lower VAP and mortality rates [11•]. A few trials on endotracheal tubes (ETTs) with novel cuffs failed to translate positive bench findings into clinical settings. In addition, meta-analyses confirmed the primary role of subglottic secretion aspiration in VAP prevention. A relatively new ETT, with an innovative cuff design, has been tested in clinical trials confirming potential value. Meta-analyses confirmed reduction of VAP with the use of chlorhexidine for oropharyngeal decontamination. However, prophylactic inhaled or oral antibiotics are ineffective. Finally, there is a growing interest in orally ingested probiotics to prevent VAP [12].

Focus of prevention of HCAI always has been the prevention of infection related to invasive devices, obviously due to iatrogenic that can occur due to invasion. Moreover, there are several topographies of HCAI that are not addressed yet; thus, it is time to think outside the box. An important topography of HCAI, for example, is hospital-acquired pneumonia not associated with mechanical ventilation (NV-HAP).

The majority of studies in the past two decades have focused primarily on VAP. However, a recent statewide study in Pennsylvania found that NV-HAP is more common than VAP; NV-HAP is associated with similar risk factors and complications than VAP and it was associated with a greater overall economic burden. Data from 2009 to 2011 revealed 5597 NV-HAP cases compared with 2299 VAP diagnoses, with equivalent mortality (18.7 and 18.9%, respectively). The total cost for NV-HAP cases was $156 million compared with $86 million for VAP [13].

Data support that risk factors for NV-HAP include age, immunocompromised status, intensive care unit admission, prolonged duration of intensive care unit or hospital stay, illness severity, underlying chronic lung disorders, and comorbid health conditions [14]. Currently, NV-HAP is not widely monitored as a preventable HAI because hospitals are not required to report or implement standards to decrease the incidence of NV-HAP. The hidden harm from NV-HAP in acute care is a significant patient safety issue that deserves attention [15].

Spite of the topography, there is a need to include engaging and educating staff, creating structures that facilitate control infection adherence and providing regular feedback on process measure performance and outcome rates.

Behavioral change strategies

It is not uncommon for infection prevention and control (IPC) interventions to be successful in one hospital yet fail or have significantly less

success, when implemented in another healthcare institution. Organizational factors have been postulated to be a major reason. As a result, there has been an increasing drive in recent years to understand and address organizational culture (OC) in order to achieve improved healthcare performance. In order to examine the inter-relationship between OC and behavioral attitudes by healthcare professionals, to determine whether and how OC may impact on IPC compliance, and to highlight the potential for OC modification interventions to improve IPC practices within hospitals, Bono et al. reviewed publications focusing on human behavior and organizational change. The authors evaluate the theory of OC within healthcare settings and identify how various elements appear to impact on IPC-related behavior. They highlight the paucity of well-designed studies but identify sporadic literature suggesting that well-designed and customized OC change initiatives can have a positive impact on IPC practices [16].

One of the most critical components of OC is the way the organization is designed and how the different jobs are arranged. This is particularly relevant in terms of organizational composition in which adequate numbers of well-trained staff are vital. Not surprisingly, outbreaks or increased endemicity of HCAI have been associated with high staff turnover and vacancies, understaffing, heavy bed occupancy, overcrowding, and increased patient turnover [17•].

We discuss some topics that have been evaluated in the literature with positive results.

Leadership role is one of this. Strong leadership, starting from the very top of any healthcare organization, has been advocated as being essential for successful IPC campaigns [18]. Hospitals with more effective leadership showed better hand hygiene compliance and improved gowning/gloving practices among staff; these institutions were also less likely to report barriers to IPC implementation [19].

Another topic is the development of multi-disciplinary teams. There is evidence that healthcare organizations that promote a culture of teamwork develop more effective IPC initiatives. The formation of multi-disciplinary clinical teams has been shown to reduce rates of hospital-acquired pneumonia in intensive care units [20].

Adherence to organizational policies has been seen as well as an effective OC. Suboptimal compliance rates are consistently reported for even basic interventions such as hand hygiene and antibiotic prophylaxis in surgery [21•]. A conceptual seminal investigation carried out by Cabana et al. identified that physicians' adherence to guidelines may be hindered by several barriers. These may include lack of awareness, lack of familiarity, lack of agreement, and lack of self-efficacy [22].

There are very few studies that demonstrating the relationship between positive job satisfaction and adherence to IPC. However, the inverse has already been demonstrated; a consistent relationship has been shown between low staff satisfaction levels and adverse outcomes such as mortality [23].

Innovation is a constant strategy in any area. Mainly, in the field of health, we have to be constantly updated and based on evidence. New technologies should and can be adopted successfully. However, some healthcare workers may fail to embrace innovative ideas that may go against (or beyond) their perceived general beliefs [24]. For this, we have to work with behavior changes. In investigating the cultural impact on

changes in behavior of medical personnel, Turnell and White proposed the "stages of change theory" as a powerful theoretical framework for both educators and targeted participants. In their application, the authors highlight that educational programs may fail unless the training provided also addresses the issues of psychological preparedness of medical staff. In addition to dissemination of information, the aim of IPC education should be to empower participants to believe in their ability to bring about the required change through their behavior [25].

Finally, the last decade has been seen an increase pressure for more extensive use of quality indicators and measures in healthcare, especially infection rates [26]. HCAI rates have been proposed as an effective marker of system failure in hospitals and it is undoubtedly an indicator of quality that must be known by the hospitalization units, the board directory, and the staffs and should be worked by all to reduce it.

Public reporting of infection rates

There is an increasing interest in public reporting of healthcare-associated infection rates in both Europe and USA, mostly for patient safety reasons.

In the USA, a study, conducted in 2006 observed that only three states publically reported HAIs; McGuckin and colleagues found that 85% of those surveyed identified HAI rates as an important factor when they were choosing a hospital [27]. Another study conducted in 2012 assessed consumer awareness, engagement, and intention to seek information on HAI rates found only 14% of respondents ranked HAIs that highly. One explanation for this difference is that HAIs are not as important as consideration when respondents are expressly asked to consider the factors of insurance, location, and referral by a healthcare worker. These findings raise questions about the usefulness of public reporting programs as they currently exist, at least as judged by the degree of consumer awareness, engagement, and intent [28].

On the other hand, in Europe, the ECDC interviewed leaders in infection control from 34 countries about HAI reporting. Many experts support the idea of publishing HAI data and acknowledged the positive influence on hospitals by increasing competition on the basis of quality, but they are hesitant about publishing infection rates as these can be misinterpreted by patients and need standardization and validation [29].

Although reporting rates did not seem to be an important factor for decrease HAIs rates, the public has a right to know what risks are before them and infection specialists should concentrate their efforts on providing meaningful and digestible information [30]. Public reporting may not actually engage the public but it does gain politicians and organizations.

Nowadays, an interesting tool to disseminate information on HAI rates is the Internet. A survey regarding HAI rates recently conducted in a hospital showed that out of them knows rates from their physician or other healthcare worker (58%) or hospital (49%) than from official state reports (38%), even though official state reports are freely accessible to anyone with Internet access [28].

Novel technology solutions such as electronic healthcare games and engagement with social media platforms may serve to support and reinforce traditional patient safety improvement initiatives.

When considering how the public interprets information on HCAI, organizations can make use of emerging communication channels such as social media platforms. There is no doubt that patients are active in such platforms [16].

Environmental cleaning

The ubiquitous environmental contamination by organisms poses an additional risk for HAI, since personal belongings of the patient and nearby surfaces are often contaminated with pathogens including multidrug resistant organisms. When these surfaces are touched by healthcare staff, pathogens may be transmitted to patients if hand hygiene compliance is low, which is the reality in most clinical settings. The impact of environmental contamination on HAI and the cost-effectiveness of surface disinfection remains a scientifically unresolved issue, despite a growing body of literature [31•]. Regarding hospital cleaning, a broad consensus exists that high standards are essential.

Recently, the use of hydrogen peroxide as a high level disinfectant to enhance environmental decontamination was performed in hospital environment with success. It is unclear, however, whether this approach should be confined to outbreak management, the terminal cleaning of isolation rooms after patient discharge from hospital or even as part of routine decontamination [32].

The new technology in this field arises as to how we can measure surface cleanliness to detect increased levels of bioburden. There are some studies aiming to highlight the utility of adenosine triphosphate (ATP) bioluminescence technology as a novel technique in detecting the degree of contamination within the sterile operating room environment or in other units.

ATP bioluminescence is a novel method to measure cleanliness and can help identify environmental trouble spots that can potentially lead to increased infection rates. Future studies correlating ATP bioluminescence findings with microbiology cultures could add to the clinical utility of this technology. Although correlation between ATP bioluminescence and clinical infection was not evaluated, it is the subject of future research. Specifically, evaluating microbiology samples taken from environmental surfaces and correlating them with increased bioburden found with ATP bioluminescence technology can help promote improved cleaning practices [33].

Although, the new products and technologies are an advance in the hospital cleaning, trainee, checklist, and staff feedback are cheap and helpful strategies that can be implemented with great success.

Hand hygiene

From the time of Ignaz Semmelweis, healthcare workers have been instructed in the principles and importance of hand hygiene. However,

there still a lack of evidence for the role of hand hygiene in preventing infections and healthcare workers' adherence to hand hygiene recommendations. Despite the wide-spread consensus that hand hygiene adherence is a cornerstone of infection control, there is a paucity of high-quality data to support its efficacy. Moreover, there is evidence that alcohol-based hand hygiene products may increase healthcare worker adherence to hand hygiene recommendations; alcohol-based hand gels do not eliminate *C. difficile* spores [34]. Although hand hygiene is the most effective strategy for preventing healthcare-associated infections, it falls short in many healthcare facilities. The compliance rate is mostly linked to system design and easily accessible hand hygiene products. Additionally, system change, healthcare worker motivation, and complex behavioral considerations should play a significant role [35•].

Hand hygiene remains challenging in healthcare institutions and monitoring and encouraging compliance with hand hygiene is laborious. Monitor hand hygiene by observation captures less than 1% of hand hygiene opportunities. Electronic monitoring tools for hand hygiene that use trigger devices and feedback to capture have become available. Although there have been several feasibility pilot studies that suggest that electronic monitoring tools may be both sensitive and specific, the cost of these systems is too high, their role in managing hand hygiene is unclear, and additional study is needed in this area [36, 37].

Antimicrobial stewardship programs (ASP)

Broad-spectrum antimicrobial use is implicated in the generation and selection of multidrug resistant bacteria. Nowadays, there is a lack of new agents to treat multidrug resistant infections, the conservation of antimicrobials is pivotal to current efforts to treat microbial infections alongside interrupting transmission through effective infection prevention. Thus, ASP aim to give structure and direction to health care institutions trying to adopt a proactive approach to tackling resistance through the prudent use of antimicrobials.

Antibiotic stewardship has been increasingly recognized as an important tool to combat antibiotic resistance, preserve current antibiotics, and improve patient care through the improvement of antibiotic prescribing at the level of the individual patient and on a larger scale for hospitals and health care systems.

Professional societies call for implementation of antimicrobial stewardship in all health care facilities and provide detailed descriptions of optimal components and implementation strategies. However, less than 50% of acute and long-term care facilities in the USA perform regular stewardship activities. The degrees to which these activities are performed are somewhat variable and often proportional to hospital size and resources. It is not always clear how much impact these activities have on inappropriate antimicrobial prescribing practices. The most common barriers to implementation of stewardship interventions include lack of personnel, lack of financial resources, opposition from prescribers, and resistance from administration. Because of the gap between guidelines and practice, health care providers need to develop ways to leverage

available resources and personnel to build and enhance antimicrobial stewardship programs [38•].

Additionally, the use of technology to change behavior in health care is receiving increased attention.

Several tools as electronic prescribing, bespoke clinical decision support tools to mobile health systems is currently used in efforts to deliver antimicrobial stewardship interventions. There is no conclusive evidence as to the impact of using different technologies in delivering antimicrobial stewardship programs or the superior efficacy of using these systems over more simple interventions. Although using existing technology has benefits of reaching a bigger audience and easier dissemination of information, technological complexity may hinder uptake of interventions [39].

Today, we live in a digital era and in addition to medical records, the use of medical applications (apps) and eBooks available by the introduction of smartphones has made possible the access of a large amount of medical knowledge with the tap of a finger at the patient's bedside. However, connectivity alone does not affect patient care.

The challenge of finding reliable accurate medical apps was highlighted in a recent publication. The investigators reviewed more than 1200 infectious diseases apps from the Apple and Google Play stores to discover only 12 apps that were developed by a health care provider [40].

Knowledge of the medical expertise involved in developing the app is crucial.

Concerns about the accuracy of drug information within medical apps have resulted in significant changes in the approval process by Apple. Apple now requires that all drug dosing recommendations within an app have a reference. It is not clear if Apple has health care professionals cross-checking the accuracy of the references, but this change clearly portrays the potential negative impact on patient care if incorrect information is used to guide therapy. Despite these concerns, the value of having immediate access to information at the point of patient care has been game changing. In addition, this technology has provided tools for ASPs around the world [39].

Considering that approximately 700,000 people die every year due to antibiotic resistant infections, with this number projected, the estimative until 2050 will surpass 10 million per year. Thus, this reinforce the benefits of antibiotic stewardship that include improved patient outcomes, reduced adverse events as *Clostridium difficile* infection, improvement in rates of antibiotic susceptibilities to targeted antibiotics, and optimization of resource utilization across the continuum of care [41].

Conclusion

HCAI must be targeted as a priority patient safety within comprehensive approaches to be tackled effectively. In addition to infections related to invasive devices whose bundles are already well established, we have to start thinking and preventing HCAI in other topographies. All preventive measures require adherence by healthcare workers that depends on behavioral changes. Organizational culture, administrative support, leadership, satisfaction, and multidisciplinary teams are new issues that have shown

positive results. On the other hand, classical subjects as hand hygiene, environmental cleaning, and prudent use of antimicrobials need to be rethinking on the set of new technologies such as the use of electronic media for alerts, consultations, and audits. The report of infection rates to the lay public is still a controversial topic but is gaining more space due to the increase in the socio-cultural level of population and the exercise of citizenship and human rights.

Compliance with Ethical Standards

Conflict of Interest
Dr. Guimaraes declares that she has no conflict of interest.
Dr. Costa declares that she has no conflict of interest.

Human and Animal Rights and Informed Consent
This article does not contain any studies with human or animal subjects performed by any of the authors.

References and Recommended Reading

Papers of particular interest, published recently, have been highlighted as:
- • Of importance

1. World Health Organization available in http://www.who.int/gpsc/country_work/burden_hcai/en/. Accessed in 03/12/2017
2. World Health Organization. Report on the burden of endemic health care-associated infection worldwide. 2011 Available in http://apps.who.int/iris/bitstream/10665/80135/1/9789241501507_eng.pdf. Accessed in 01/01/2018
3. Cassini A, Plachouras D, Eckmanns T, et al. Burden of six healthcare-associated infections on European population health: estimating incidence-based disability-adjusted life years through a population prevalence-based modelling study. PLoS Med. 2016;13:e1002150.
4. • Allegranzi B, Kilpatrick C, Storr J, Kelley E, Park BJ, Donaldson L. Global infection prevention and control priorities 2018–22: a call for action. Lancet Glob Health. 2017;5(12):e1178–80.

In this article the authors call attention to the need for international organizations to recognize that global health security relies on effective infection prevention and control program to control emerging health threats (including antimicrobial resistance) and that there is a need to intensify the support to countries and the international community.

5. Cardo D, Dennehy PH, Halverson P, Fishman N, Kohn M, Murphy CL, et al. Moving toward elimination of healthcare-associated infections: a call to action. Infect Control Hosp Epidemiol. 2010;31(11):1101–5.
6. World Health Organization. Core components for infection prevention and control programmes: Report of the second meeting, Informal Network on Infection Prevention and Control in Health Care, Geneva, Switzerland, 26–27 June 2008. 2009.
7. Resar R, Griffin F, Haraden C, Nolan T. Using care bundles to improve health care quality. IHI innovation series white paper Cambridge. Institute for Healthcare Improvement: Massachusetts; 2012.
8. Ista E, van der Hoven B, Kornelisse RF, van der Starre C, Vos MC, Boersma E, et al. Effectiveness of insertion and maintenance bundles to prevent central-line-associated bloodstream infections in critically ill patients of all ages: a systematic review and meta-analysis. Lancet Infect Dis. 2016;16(6):724–34.
9. • Reyes DCV, Bloomer M, Morphet J. Prevention of central venous line associated bloodstream infections in adult intensive care units: a systematic review. Intensive Crit Care Nurs. 2017;43:12–22.

In this systematic review, the authors identify and critique the best available evidence regarding interventions to prevent central venous line associated bloodstream infections in adult intensive care unit patients other than anti-microbial catheters.

10. Entesari-Tatafi D, Orford N, Bailey MJ, Chonghaile MN, Lamb-Jenkins J, Athan E. Effectiveness of a care bundle to reduce central line-associated bloodstream infections. Med J Aust. 2015;202(5):247–9.

11.• Klompas M. What is new in the prevention of nosocomial pneumonia in the ICU? Curr Opin Crit Care. 2017;23(5):378–84.
The author summarizes and contextualizes recent evidences on preventing ventilator-associated pneumonia and suggests new ways to optimize the selection of ventilator bundle components and their implementation.
12. Li Bassi G, Senussi T, Aguilera XE. Prevention of ventilator-associated pneumonia. Curr Opin Infect Dis. 2017;30(2):214–20.
13. Davis J, Finley E. The breadth of hospital-acquired pneumonia: non-ventilated versus ventilated patients in Pennsylvania. Pa Patient Saf Advis. 2012;9:99–105.
14. Montravers P, Harpan A, Guivarch E. Current and future considerations for the treatment of hospital-acquired pneumonia. Adv Ther. 2016;33:151–66.
15. Baker D, Quinn B. Hospital Acquired Pneumonia Prevention Initiative-2: incidence of non-ventilator hospital-acquired pneumonia in the United States. Am J Infect Control. 2017; https://doi.org/10.1016/j.ajic.2017.08.036.
16. Bono SD, Heling G, Borg MA. Organizational culture and its implications for infection prevention and control in healthcare institutions. J Hosp Infect. 2014;86:1–6.
17.• Griffiths P, Renz A, Hughes J, Rafferty AM. Impact of organization and management factors on infection control in hospitals: a scoping review. J Hosp Infect. 2009;74:1–14.
This scoping review sought evidence about organizational and management factors affecting infection control in general hospital settings. The organizational characteristics identified in this review should be considered risk factors for infection.
18. Saint S, Kowalski CP, Banaszak-Holl J, Forman J, Damschroeder L, Krein SL. The importance of leadership in preventing healthcare associated infection: results of a multistate qualitative study. Infect Control Hosp Epidemiol. 2010;31:901–7.
19. Sinkowitz-Cochran RL, Burkitt KH, Cuerdon T, et al. The associations between organizational culture and knowledge, attitudes and practices in multicenter Veterans Affairs quality improvement initiative to prevent methicillin-resistant *Staphylococcus aureus*. Am J Infect Control. 2012;40:138–43.
20. Kay J, Ashline V, Erickson D. Critical care bug team: a multidisciplinary team approach to reducing ventilator-associated pneumonia. Am J Infect Control. 2000;28:197–201.
21.• Boyce JM. Update on hand hygiene. Am J Infect Control. 2013;41:S94–6.
The author discuss recent developments related to hand hygiene including new test methods for evaluating hand hygiene products, improvements in alcohol-based hand rubs, novel methods of hand antisepsis, and new strategies and technologies for monitoring hand hygiene practices among health care personnel.
22. Cabana MD, Rand CS, Powe NRP, et al. Why don't physicians follow clinical practice guidelines? A framework for improvement. JAMA. 1999;282:1458–65.
23. Aiken LH, Clarke SP, Cheung RB, Sloane DM, Silber JH. Educational levels of hospital nurses and surgical patient mortality. JAMA. 2003;290:1617–23.
24. Saint S, Kowalski CP, Banaszak-Holl J, Forman J, Damschroder L, Krein SL. How active resisters and organizational constipators affect health-care acquired infection prevention efforts. Joint Comm J Qual Imag. 2009;35:239–46.
25. Turnell EP, White GL. Using behavior change theories to enhance hand hygiene behavior. Educ Health (Abingdon). 2005;18:80–4.
26. Castro-Sanchez E, Holmes AH. Impact of organizations on healthcare-associated infections. J Hosp Infect. 2015;89:346–50.
27. McGuckin M, Waterman R, Shubin A. Consumer attitudes about health care-acquired infections and hand hygiene. Am J Med Qual. 2006;21:342–6.
28. McGuckin M, Govednik J, Hyman D, Black B. Public reporting of health care–associated infection rates: are consumers aware and engaged? Am J Med Qual. 2014;29(1):83–5.
29. Martin M, Zingg W, Hansen S, Gastmeier P, Wu AW, Pittet D, et al. on behalf of the PROHIBIT study group. Public reporting of healthcare-associated infection data in Europe. What are the views of infection prevention opinion leaders? J Hosp Infect. 2013;83:94–8.
30. Kiernan MA. Public reporting of healthcare-associated infection: professional reticence versus public interest. J Hosp Infect. 2013;83:92–3.
31.• Dancer SJ. The role of environmental cleaning in the control of hospital acquired infection. J Hosp Infect. 2009;73:378–85.
This review examines the links between the hospital environment and various pathogens, including meticillin-resistant *Staphylococcus aureus*, vancomycin-resistant enterococci, norovirus, *Clostridium difficile*, and *Acinetobacter spp.*
32. French GL, Otter JA, Shannon KP, Adams NMT, Watling D, Parks MJ. Tackling contamination of the hospital environment by methicillin-resistant *Staphylococcus aureus* (MRSA): a comparison between conventional terminal cleaning and hydrogen peroxide vapour decontamination. J Hosp Infect. 2004;57:31–7.
33. Richard RD, Bowen TR. What orthopaedic operating room surfaces are contaminated with bioburden? A study using the ATP bioluminescence assay. Clin Orthop Relat Res. 2017;475(7):1819–24.
34. Gould DJ, Chudleigh JH, Moralejo D, Drey N. Interventions to improve hand hygiene compliance in patient care. Cochrane Database Syst Rev. 2007;2:CD005186.
35.• Al-Tawfiq JA, Pittet D. Improving hand hygiene compliance in healthcare settings using behavior change theories: reflections, Teaching and Learning. Medicine. 2013;25(4):374–82.
This article discusses the application of behavioral theories in hand hygiene promotion in a theoretical manner. The program relies on the trans theoretical model of health behavior change, John Keller's model of motivational design, and the theory of planned behavior.

36. Boyce JM. Measuring healthcare worker hand hygiene activity: current practices and emerging technologies. Infect Control Hosp Epidemiol. 2011;32:1016–28.
37. Morgan DJ, Pineles L, Shardell M, et al. Automated hand hygiene count devices may better measure compliance than human observation. Am J Infect Control. 2012;40:955–9.
38.• Society for Healthcare Epidemiology of America. Policy statement on antimicrobial stewardship by the Society for Healthcare Epidemiology of America (SHEA), the Infectious Diseases Society of America (IDSA), and the Pediatric Infectious Diseases Society (PIDS). Infect Control Hosp Epidemiol. 2012;33(4):322–7.
This article is a position statement of the Society for Healthcare Epidemiology of America, the Infectious Diseases Society of America, and the Pediatric Infectious Diseases Society of America that outlines recommendations for the mandatory implementation of antimicrobial stewardship throughout health care, suggests process and outcome measures to monitor these interventions, and addresses deficiencies in education and research in this field as well as the lack of accurate data on antimicrobial use in the USA.
39. Kullar R, Goff DA. Transformation of antimicrobial stewardship programs through technology and informatics. Infect Dis Clin N Am. 2014;28:291–300.
40. Moodley A, Mangino JE, Goff DA. Review of infectious diseases applications for iPhone/iPad and Android: from pocket to patient. Clin Infect Dis. 2013;57(8):1145–54.
41. O'Neill J. Review on antimicrobial resistance: tackling drug-resistant infections globally—final report and recommendations (Wellcome Trust, UK Government, 2016). Available at: http://amr-review.org/sites/default/files/160518_Final paper_with cover.pdf. Accessed on 05 december 2017.