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Commentary

The learning hospital: From theory to practice in a hospital infection prevention program

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Abstract

The learning hospital is distinguished by ceaseless evolution of erudition, enhancement, and implementation of clinical best practices. We describe a model for the learning hospital within the framework of a hospital infection prevention program and argue that a critical assessment of safety practices is possible without significant grant funding. We reviewed 121 peer-reviewed manuscripts published by the VCU Hospital Infection Prevention Program over 16 years. Publications included quasi-experimental studies, observational studies, surveys, interrupted time series analyses, and editorials. We summarized the articles based on their infection prevention focus, and we provide a brief summary of the findings. We also summarized the involvement of nonfaculty learners in these manuscripts as well as the contributions of grant funding. Despite the absence of significant grant funding, infection prevention programs can critically assess safety strategies under the learning hospital framework by leveraging a diverse collaboration of motivated nonfaculty learners. This model is a valuable adjunct to traditional grant-funded efforts in infection prevention science and is part of a successful horizontal infection control program.

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> *"Discovery is not necessarily a function of special talent, but a function of hard work, which creates talent, and low achievement is less commonly from a lack of time and resources, it is more from a lack of willpower."*
> Dr. Santiago Ramón y Cajal
> Nobel Prize in Physiology and Medicine 1906

The concept of the learning hospital is distinguished by ceaseless evolution of erudition, enhancement, and implementation. A learning hospital, where "science, informatics, incentives and culture are aligned for continuous improvement and innovation (p 16)," need not be supported by additional funding from the healthcare system.[1] Instead, it is a culture within the system that seeks evidence-based and value-driven results through facilitating an environment in which nonfaculty learners at all levels are engaged in research and the pursuit of scientific advancement. In the learning hospital setting, knowledge is collaboratively gained and shared, leading to improved patient care, higher quality, and lower costs.[2] Knowledge based on local data can support practice changes and enhanced implementation. However, no models of the learning hospital as applied to healthcare infection prevention have been published.

We reviewed the entirety of our published manuscripts from January 2004 to June 2019 under the framework of the learning hospital. These references were reviewed by authors O.H., K.A., and M.S. Publications authored by members of the Virginia Commonwealth University (VCU) Healthcare Infection Prevention Program (HIPP) were excluded if they were coauthored with practitioners from outside hospitals or the research setting was outside the VCU Health System (VCUHS). All publications related to any component of our infection prevention program were included in this review. Although the bulk of our published work is in infection prevention, we included infectious diseases clinical publications that were cowritten by learners consistent with the concept of the learning hospital. These published manuscripts were divided into areas of focus based on the infection control topic or intervention: hand hygiene, universal gloving, contact precautions, healthcare worker apparel, personal protective equipment, bare below the elbows, antimicrobial stewardship, chlorhexidine bathing, environmental disinfection, methicillin-resistant *Staphylococcus aureus* (MRSA) and other multidrug-resistant organisms, surgical site infections, perspectives on hospital-acquired infections and patient safety, diagnostic test stewardship, gastrointestinal infections/*C. difficile*, *S. aureus*, patient decolonization, compliance with process of care measures, oncology care, implications for infection control best practice, and editorials. We summarized the publications by describing how each manuscript is relevant to the mission of the infection prevention program. We report the involvement of nonfaculty learners (eg, students, interns, residents, fellows and infection preventionists [IPs]) in the varied research projects, and we tallied the number

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of publications that were funded by grants. The attending physicians of the VCU HIPP over the past 16 years are termed faculty learners in this summary.

The Healthcare Infection Prevention Program at VCUHS, an urban, 865-bed hospital, performs hospital-wide surveillance according to the Centers for Disease Control and Prevention's National Healthcare Safety Network methodology. A medical director, who is both the chair of the division and a hospital epidemiologist, and a nursing director lead the HIPP. The leadership team also includes 3 associate hospital epidemiologists, 1 of whom leads our antimicrobial stewardship program, which is administered within the HIPP. In addition to HIPP leadership, 10 trained and certified IPs develop policies and procedures to minimize hospital-acquired infections (HAIs) and offer hospital disinfection recommendations. The HIPP also includes a nurse clinician who oversees the unique pathogen unit, a medical technologist, an executive secretary, a program support assistant, a data analyst, an information technologist, and a full-time project coordinator for the hand hygiene monitoring program. Important HIPP changes over the last 16 years have included the addition of the aforementioned hospital-supported data analyst who assists with research coordination (added in 2013) and a dedicated third-year infectious diseases fellowship (1 fellow per annum) in infection prevention (added in 2014).

The HIPP prioritizes weekly staff meetings, monthly Infection Control Committee (ICC) and monthly Champions of Healthcare Infection Prevention (CHIPs) meetings. The ICC consists of all members of the HIPP department; pharmacists; microbiologists; and regulatory, nursing, physician, operating room (OR), and central sterile staff members. The CHIPs include nurses from each inpatient hospital unit. During CHIP meetings, IPs share infection prevention knowledge and practice changes with the CHIPs. The CHIPs then share this information with the nurses and other employees of their respective units. Through a strong core HIPP team, nonfaculty learners, and monthly collaborative meetings, infection prevention practices are enhanced and knowledge is gained and shared.

The HIPP team actively partners with and mentors a diversity of nonfaculty learners in the healthcare system. Nonfaculty learners include college and medical students, interns, residents (both medical and pharmacy), fellows, IPs, non-IP nurses, and non-IP HIPP staff. Nonfaculty learners actively seek research experience within the HIPP, and their involvement in the program is encouraged. Since 2003, 87 nonfaculty learners have contributed to HIPP research and manuscript publication. Nonfaculty learners actively participate in multiple HIPP functions, including attending meetings, project design, and data collection and analysis, all to serve the quality and safety mission of the institution. Herein, we describe a learning hospital model in which collaboration among staff and nonfaculty learners results in the critical exploration and assessment of a horizontal infection prevention program.

Members of the HIPP published 121 manuscripts consistent with the theme of the learning hospital: 92 original investigations, 21 perspectives and editorials, and 8 case reports (Table 1). HIPP members also published 12 clinical infectious diseases manuscripts on H1N1 influenza, fungal infections, HIV/AIDS, bacteremia/septic shock, and uncommon infectious diseases under the learning hospital framework.[3–14] Only 4 of 121 (3%) of the publications were funded by grants. Of all the manuscripts published, 85 of 121 (70%) involved either a student, intern, resident, fellow, infection preventionist, non-IP HIPP staff, or non-IP nurses. The learners included 9 college students involved with 8 manuscripts, 16 medical students involved with 18 manuscripts, 4 graduate students involved with 13 manuscripts, 11 interns or residents involved with 13 manuscripts, 19 ID fellows involved with 36 manuscripts, and 6 infection preventionists involved with 15 manuscripts. A total of 62 nonfaculty learners (ie, students, interns, residents, fellows, IPs, non-IP HIPP staff, and non-IP nurses) were either first or second authors, representing 77 of 121 (64%) of all manuscripts published by members of the HIPP. Since 2016, the number of nonfaculty learners as first and/or second authors of published manuscripts has continued to increase (Fig. 1 and Table 2). As of June 2019, the HIPP has had a total of 17 publications, all with nonfaculty learners as first and/or second authors (Fig. 1 and Table 2). Notably, the first and second authors of this manuscript (O.H. and M.S) are college students. Furthermore, we sought to analyze the trend of nonfaculty physicians (ie, medical students, residents, and fellows) as first or second authors over the past 16 years (Fig. 2).

Broad collaborations in infectious diseases research are important given a decline in academic infectious diseases as a career choice. In a 2015 commentary, Edmond and Wenzel explore disturbing trends and challenges in infectious diseases as a career.[15] The decline of infectious disease physicians in academic medicine is largely driven by an unbalanced focus on the business model of medicine, highlighting rapid patient transactions linked to professional income with financial incentives for high-volume care.[15] This focus is coupled with greater reliance on electronic medical records and the absence of shared physical spaces, such as physician-faculty lounges, for conversation and reflection with colleagues.[16] The result is the primacy of patient volume over value, physician discussion, and/or academic collaboration. The looming shortage of infectious diseases physicians and even fewer hospital epidemiologists further challenges research and patient safety.[17]

The time-honored research model is based on grant-funded support, with the faculty member's time protected, typically >50% of effort, to focus on a specific area of interest. Grant funding further facilitates the hiring of study personnel as investigative assistants and collaborators. Given the priority of relative value unit (RVU) medicine and intense competition for limited funding in hospital infection prevention and safety, a novel approach is required to encourage academic infection prevention work in the current era.

We provide an example of the learning hospital under the framework of infection prevention. A horizontal infection prevention strategy minimizes the cross-transmission of organisms via the most common mechanism, contact.[18] In our published studies, we sought to challenge paradigms such as physician attire, the introduction of bare below the elbows, and the use of contact precautions for the control of endemic pathogens, specifically MRSA and VRE. We observed that the discontinuation of contact precautions (CP) for MRSA- or VRE-colonized patients resulted in no significant adverse patient outcomes and drove an institutional practice change.[19] We further explored multiple aspects of the infection prevention program, including the donning and doffing of personal protective equipment, daily and terminal room disinfection, the deployment of touchless UV-C technologies in both acute-care settings and the operating room, hand hygiene, patient chlorhexidine-gluconate bathing, and our antimicrobial stewardship strategies. All of these studies, intended to change perspectives within our institution, frequently resulted in local practice and policy changes. Through our analysis in these studies, we were able to determine whether our interventions had an effect on HAIs in our health system.

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Table 1. Summary of Learning Hospital Infection Prevention Projects

References	Lessons Learned and Resultant Impact on VCU Infection Prevention Practice
Hand hygiene	
• Approaches to hand hygiene monitoring: from low to high technology approaches –Masroor et al[23] • Watching them wash: description of a hand hygiene observation program –Stevens et al[24] • Barriers, perceptions and compliance: hand hygiene in the operating room and endoscopy suite –Pedersen et al[25] • Hand hygiene compliance monitoring: the state of the art –Jarrin et al[26] • Successful use of alcohol sensor technology to monitor and report hand hygiene compliance –Edmond et al[27]	• A review of HH observation strategies supports the use of a trained, covert HH observation team for optimal HH performance data. • Our initial assessment of wireless HH monitoring technology ultimately resulted in the adoption HH technology in our healthcare system (2019).
Universal gloving	
• Perceptions and barriers to universal gloving for infection prevention: a survey of healthcare workers and patients –Masroor et al[28] • Mandatory gloving in acute care pediatric units associated with decreased risk of hospital-acquired infection –Bearman[29] • Trial of universal gloving with emollient impregnated gloves to promote skin health, improve hand hygiene, and prevent the transmission of multidrug-resistant organisms in a surgical ICU –Bearman et al[30] • A controlled trial of universal gloving vs contact precautions for preventing the transmission of multidrug-resistant organisms –Bearman et al[31]	• Universal gloving is a safe alternative to contact precautions for endemic pathogens provided that HH is sustained. • Universal gloving challenges the paradigm that CPs are necessary for the control of endemic pathogens.
Contact precautions	
• Impact of discontinuation of contact precautions on central-line associated bloodstream infections in an academic children's hospital – Godbout et al[32] • Control of drug-resistant pathogens in endemic settings: contact precautions, controversies, and a proposal for a less restrictive alternative –Bearman et al[33] • Impact of discontinuing contact precautions for mrsa and vre: an interrupted time series analysis –Bearman et al[19] • Duration of contact precautions in acute-care settings –Banach et al[34] • Contact precautions for multi-drug resistant organisms—reply –Morgan et al[35] • Contact precautions for endemic MRSA and VRE: time to retire legal mandates –Morgan et al[36] • Reconsidering contact precautions for endemic MRSA and VRE –Morgan et al[37] • Effect of contact precautions on wait time from emergency room disposition to inpatient admission –McLemore et al[38] • The impact of discontinuing contact precautions for VRE and MRS on device-associated infections –Edmond et al[39]	• With a robust horizontal infection prevention platform, CP had no impact on device-associated HAI rates in adults or CLABSIs in children. • Critical assessment of CP for endemic pathogens resulted in significant institutional policy and practice change.
Healthcare worker apparel	
• Letter to the editor regarding "Healthcare personnel attire in non-operating-room settings" –Bearman[40] • Transmission of nosocomial pathogens by white coats: an in vitro model –Butler et al[41] • A crossover trial of antimicrobial scrubs to reduce MRSA burden on healthcare worker apparel –Bearman et al[42]	• HCW apparel is colonized with potential pathogens during the course of wear, this may play a role in the transmission of HAIs. • Antimicrobial scrubs may impact bioburden on apparel, however bacterial burden of hands is not significantly reduced with antimicrobial scrubs, thus HH remains the primary focus to minimize cross transmission.
Personal protective equipment	
• Acceptability and necessity of training for optimal personal protective equipment (PPE) use –Doll et al[43] • The increasing visibility of the threat of healthcare worker self-contamination –Doll and Bearman[44]	• Consistent and precise use of PPE, including a 1-step method of doffing, allows for optimal protection from self-contamination. • Brief instructional video for PPE donning/doffing as part of annual mandatory staff and provider education.

Bare below the elbows	
• Bare below the elbows in an academic medical center –Godbout et al[45] • Seasonal variation in bare-below-the-elbow compliance –Masroor et al[46] • Healthcare worker perceptions of bare below the elbows: readiness for change? –Pellerin et al[47]	• Long sleeves are colonized during HCW shifts due to the inability disinfect fabric between patient care, a BBE approach may prevent HAI transmission. • HCWs value apparel with pockets, therefore, team vests were instituted as an alternative to the traditional white coat. • Compliance with BBE is normative behavior and significant without a mandate.
Antimicrobial stewardship	
• Knowledge, attitudes, and practices of bedside nursing staff regarding antibiotic stewardship: a cross-sectional study –Abbas et al[48] • Rapid respiratory panel testing: impact of active antimicrobial stewardship –Abbas et al[49] • De-escalating antibiotic use in the inpatient setting: strategies, controversies, and challenges –Markley et al[50] • Effect of carbapenem restriction on prescribing trends for immunocompromised wards at an academic medical center –Kirk et al[51] • Carbapenem-resistant Enterobacteriaceae at a low prevalence tertiary care center: patient level risk factors and implication for an infection prevention strategy –Doll et al[52] • A survey to optimize the design of an antimicrobial stewardship and infectious disease smartphone app at an academic medical center –Markley et al[53] • Surgeons do not listen: evaluation of compliance with antimicrobial stewardship program recommendations –Duane et al[54] • Guarding the goods: an introduction to antimicrobial stewardship –Wang J et al[55] • Antimicrobial stewardship practices in Virginia –Lee et al[56] • Antimicrobial stewardship program members' perspectives on program goals and national metrics –Van Parys et al[57] • Pediatric antimicrobial stewardship: state of the art –Godbout[58] • Performance of a novel antipseudomonal antibiotic consumption metric among academic medical centers in the United States –Markley et al[59] • Description of a restriction program for gram-positive antimicrobial agents at an academic medical center –Molayi et al[60] • An examination of stewardship interventions by major category in an urban, academic medical center –Pellerin et al[61] • Facilitators and barriers to implementing antimicrobial stewardship strategies: results from a qualitative study –Pakyz et al[62] • An evaluation of the association between an antimicrobial stewardship score and antimicrobial usage –Pakyz et al[63] • Managing antibiotic resistance –Wenzel and Edmond[64] • The current state of antimicrobial stewardship: challenges, successes and future directions –Emberger et al[65] • The role of the hospital epidemiologist in antibiotic stewardship –Abbas et al[66] • Antibiotic prevention of acute exacerbations of COPD –Wenzel et al[67] • The effectiveness of formulary restriction and preauthorization at an academic medical center –Kirk et al[68]	• Key barriers to nurse participation in AS-related activities include time constraints, physician pushback, and unfamiliarity with AS practices. • Challenges to ADE arise when clinicians lack confidence due to their uncertainty in culture data, thus requiring a high degree of clinical judgement. • Development of CRE is facilitated through antimicrobial pressure, elucidating the role of AS programs in targeting CRE. • Inpatient surgical services demonstrate poor compliance with AS guidelines. • Poor usability, cost and out of date information are primary deterrents for using medical mobile applications, while simple design and organization are valued. • Implementation of formulary restriction and preauthorization is effective in limiting, and occasionally reducing antimicrobial consumption.

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Table 1. (*Continued*)

References	Lessons Learned and Resultant Impact on VCU Infection Prevention Practice
Chlorhexidine bathing	
• Chlorhexidine gluconate bathing: Patient perceptions, practices, and barriers at a tertiary-care center –Vanhoozer et al[69] • You get back what you give: decreased hospital infections with improvement in CHG bathing, a mathematical modeling and cost analysis –Reagan et al[70]	• CHG bathing reduces the risk for HAIs. • Electronic medical record documentation is an acceptable tool for monitoring and improving CHG bathing compliance. • Ongoing education is essential to improve bathing compliance and high quality bathing of self-care patients. • Mathematical modeling analysis was employed to assess the incremental impact of heightened CHG bathing.
Environmental disinfection	
• Deployment of a touchless ultraviolet light robot for terminal room disinfection: the importance of audit feedback –Fleming et al[71] • Environmental cleaning and disinfection of patient areas –Doll et al[72] • Barriers and perceptions of environmental cleaning: an environmental services perspective –Pedersen et al[73] • Ultraviolet-C light as a means of disinfecting anesthesia workstations –Nottingham et al[74] • Touchless technologies for decontamination in the hospital: a review of hydrogen peroxide and UV devices –Doll et al[75] • Disinfection of noncritical equipment on units with high hospital-onset *Clostridium difficile* infections –Bowe et al[76]	• Tru-D technology allows for effective UVC decontamination of hospital surfaces, with no significant difference between the reduction of CFU levels on simple versus complex surfaces. • UVC technology has garnered 99.8% efficacy in reduction of environmental *C. difficile*, thus enhancing cleanliness and decreasing the risk of HAIs. • HAIs can be reduced through the use of copper, an antimicrobial material, as a coating over high-touch facilities with large bioburdens between cleanings. • The general understanding of effective sanitation of NCIs within 4 surveyed hospital units fell short of optimal awareness. • Significant barriers to NCI disinfection were perceived as lack of time and lack of educational materials.
Multidrug-resistant organisms	
• Central nervous system infections due to vancomycin-resistant enterococci: case series and review of the literature –Wang et al[77] • *Achromobacter* spp endocarditis: a case report and literature review –Derber et al[78] • Endocarditis due to vancomycin-resistant enterococci: case report and review of the literature –Stevens and Edmond[79]	• Case series/reports and treatment options for central nervous system infections with drug-resistant pathogens.
Methicillin-resistant *Staphylococcus aureus* – MRSA	
• Screening inpatients for MRSA—case closed –Edmond and Wenzel[80] • Screening for MRSA: a flawed hospital infection control intervention –Wenzel et al[81] • The rising tide: skin and soft-tissue infections due to community-associated methicillin-resistant *Staphylococcus aureus* –Stevens and Edmond[82] • Community-acquired methicillin resistant *Staphylococcus aureus* in a women's collegiate basketball team –Stevens et al[83] • Active surveillance cultures are not required to control MRSA infection in the critical care setting –Edmond et al[84] • Nasal carriage of inducible dormant and community-associated methicillin-resistant *Staphylococcus aureus* in an ambulatory population of predominantly university students –Bearman et al[85] • Community-acquired methicillin-resistant *Staphylococcus aureus* (MRSA): new issues for infection control –Wenzel et al[86]	• The singular focus that hospitals give MRSA screening is flawed; the basis of infection prevention is a horizontal infection prevention strategy. • Device-associated MRSA infections in the critical care setting can be controlled without active surveillance. • Community-acquired MRSA remains an ongoing concern among certain populations. • The increased virulence of community-acquired MRSA, alongside decreased immunity of patients, may heighten morbidity and mortality.
Surgical site infections	
• Infection prevention and enhanced recovery after surgery: a partnership for implementation of an evidence-based bundle to reduce colorectal surgical site infections –Albert et al[87] • Surgical site infection surveillance for neurosurgical procedures: a comparison of passive surveillance by surgeons to active surveillance by infection control professionals –Heipel et al[88]	• Traditional infection prevention SSI risk reduction strategies are more reliably implemented within an ERAS model.

Perspectives and original research on hospital-acquired infections and patient safety	
• Influence of state laws mandating reporting of healthcare associated infections: the case of central line-associated bloodstream infections –Pakyz and Edmond[89] • Hospital-acquired infections under pay-for-performance systems: an administrative perspective on management and change –Vokes et al[90] • The impact of hospital-acquired bloodstream infections –Wenzel and Edmond[91] • Outcomes of patients with alcohol use disorders experiencing healthcare-associated infections –De Wit et al[92] • Practices and an assessment of healthcare workers' perceptions of compliance with infection control knowledge of nosocomial infections –Berhe et al[93] • Susceptibility of coagulase-negative staphylococcal nosocomial bloodstream isolates to the chlorhexidine/silver sulfadiazine-impregnated central venous catheter –Rosato et al[94] • Comparison of the systemic inflammatory response syndrome between monomicrobial and polymicrobial pseudomonas aeruginosa nosocomial bloodstream infections –Marra et al[95] • A statewide survey of nosocomial infection surveillance in acute-care hospitals –Edmond et al[96] • Infection control and the prevention of nosocomial infections in the intensive care unit –Bearman et al[97] • Systemic inflammatory response syndrome in nosocomial bloodstream infections with *Pseudomonas aeruginosa* and *Enterococcus* spp: comparison of elderly and nonelderly patients –Marra et al[98] • Comparison of severity of illness scoring systems for patients with nosocomial bloodstream infection due to *Pseudomonas aeruginosa* –Marra et al[99] • Systemic inflammatory response syndrome in adult patients with nosocomial bloodstream infections due to enterococci –Bar et al[100] • Who is steering the ship? External influences on infection control programs –Edmond and Eickhoff[101] • Infection control: the case for horizontal rather than vertical interventional programs –Wenzel and Edmond[102]	• There is no evidence that CLABSI incidence is impacted by mandatory public reporting laws. • Increasing PFP systems could create a loss of reimbursement for hospitals that do not effectively prevent HAIs. • AUD patients have longer LOS, increased mortality, and higher costs compared to patients without AUD. • IC education programs need to be modified per occupations, as HCW perceptions of IC implementation vary by occupations. • A majority of deadly nosocomial bloodstream infections (BSIs) take place in ICUs. • Comprehensive programs with "evidence-based" IC guidelines are needed to reduce risk of nosocomial BSIs in ICUs. • A survey of surveillance techniques revealed that the infrastructure for IC in Virginia hospitals remains underdeveloped.
Diagnostic test stewardship	
• Test stewardship, frequency and fidelity: impact on reported hospital-onset *Clostridioides difficile* –Fleming et al[103] • Urine test stewardship for catheterized patients in the critical care setting: provider perceptions and impact of electronic order set interventions –Lin et al[104]	• Implementation of diagnostic test stewardship is challenging. • EMR-based decision support for *C. difficile* and urine test stewardship has been utilized in our institution.
GI infections/*C. difficile*	
• *Clostridioides difficile*–associated diarrhea: infection prevention unknowns and evolving risk reduction strategies –Doll et al[105] • Hospital-acquired *Clostridium difficile*-associated disease in the intensive care unit setting: epidemiology, clinical course and outcome –Marra et al[106] • Diagnosis and management of common gastrointestinal tract infectious disease in ulcerative colitis and Crohn's disease patients –Landsman et al[107] • *Clostridioides difficile* Nurse-driven protocol: a cautionary tale –Kavazovic et al[108]	• *C. difficile* remains a difficult HAI to control and the best strategies to do so remain in question. • Advanced age and increased severity of *C. difficile* infection at onset are independent predictors of death among those with *C. difficile*. • Distinction between the diagnoses of CDI and IBD is critical in treatment. • Highly sensitive and specific testing is the ideal way to quickly distinguish between CDI and IBD and initiate proper treatment. • Implementation of a NDP failed to increase early identification of CO *C. difficile*; study showed low NDP testing fidelity and poor test stewardship.
***Staphylococcus aureus* infections**	
• Are gym surfaces reservoirs for *Staphylococcus aureus*? A point prevalence survey –Markley et al[109] • Time to blood culture positivity as a predictor of clinical outcome of *Staphylococcus aureus* bloodstream infection –Marra et al[110]	• Gymnasiums can act as reservoirs for staphylococci, allowing for the spread of infection in a community. • The presence of MSSA on gym surfaces indicates that MRSA is biologically capable of remaining viable as well.

(*Continued*)

Table 1. (*Continued*)

References	Lessons Learned and Resultant Impact on VCU Infection Prevention Practice
Patient decolonization	
• Universal staphylococcal decolonization for elective surgeries: The patient perspective –Masroor et al[111] • Healthcare worker perceptions of and barriers to universal staphylococcal decolonization in elective orthopaedic joint surgeries. –Masroor et al[112]	• Universal staphylococcal decolonization diminishes the risk of *S. aureus* SSIs. • Hospital staff are more resistant to USD among orthopedic surgical patients.
Compliance and process of care measures	
• Continued noncompliance with the American College of Surgeons recommendations to decrease infectious exposure in the operating room: why? – Welc et al[113] • Impact of 2 different levels of performance feedback on compliance with infection control process measures in 2 intensive care units –Assanasen et al[114] • Measurement and feedback of infection control process measure in the intensive care unit: impact on compliance –Berhe et al[115]	• Many surgeons are unaware of updated American College of Surgeons guidelines which leads to noncompliance of IC practices. • Compliance feedback has been shown to improve infection control process measures.
Oncology care and infection prevention	
• Healthcare-associated transmission of hepatitis B and C in oncology care –Stevens and Edmond[116] • Infection probability score shows 59.4% specificity and 74.3% sensitivity for predicting infection in haematology-oncology patients –Bearman[117]	• Enhancing IC practices in oncology environments is crucial in averting health care transmission of hepatitis B and C to increasingly immunocompromised patients.
Implications for infection prevention best practice	
• Lessons from severe acute respiratory syndrome (SARS): implications for infection control –Wenzel et al[118] • Pushing beyond resistors and constipators: implementation considerations for infection prevention best practices –Bearman and Stevens[119] • Survey of infection prevention best practices in a university ob/gyn service: barriers, obstacles and uncertainties. –Arquiette et al[120]	• SARS provided education that should be applied to all epidemics: the need for individual reporting, the importance of IT communication, the role of the WHO, and the significance of physicians identifying a new disease/syndrome. • To handle IP "resistors and constipators," early buy-in is needed. Otherwise, it is important to work about them or cancel their employment status.
Bloodstream infections in immunocompromised hosts	
• Utility of surveillance blood cultures in patients undergoing hematopoietic stem cell transplantation –Ghazal et al[121] • Use of intravenous immunoglobulin in critically ill patients –Donovan and Bearman[122]	• Surveillance blood cultures can result in over diagnosis and treatment, which will create the overuse of antibiotics, leading to increased antibiotic resistance. • Current literature does not support the use of IVIG therapy for sepsis, TSS, myocarditis, and severe H1N1 infections.
Infection prevention editorials	
• Hospital infection prevention: how much can we prevent and how hard should we try? –Bearman et al[123] • Averting a betrayal of trust: system and individual accountability in healthcare infection prevention –Bearman and Vokes[124] • Infection prevention in the hospital from past to present. evolving roles and shifting priorities –Doll et al[125] • Infection control precautions for visitors to healthcare facilities –Banach et al[126] • An unconventional house call –Bearman[127] • Mandatory public reporting in the USA: an example to follow? –Edmond and Bearman[128] • Getting to zero: is it safe? –Edmond[129]	• Editorials can be an effective way to communicate an infection prevention message especially in healthcare settings with inadequate funding and delays in advancement of infection prevention efforts. • The law of diminishing returns demonstrates that the goal of 0 HAIs may be impossible. • Allocation of appropriate resources are necessary to manage evolving infection prevention goals as healthcare systems become increasingly focused on regulatory targets. • Commitment to the maintenance of strong horizontal infection prevention efforts are necessary for sustained and continued reduction of HAIs. • Investments in additional vertical infection prevention efforts should be closely analyzed to determine what additional value these strategies would bring to a horizontal infection prevention platform.

Note. ADE, antibiotic de-escalation; ARV, antiretroviral; AS, antimicrobial stewardship; AUD, alcohol use disorder; BBE, bare below the elbows; BSI, bloodstream infection; CDI, *Clostridioides difficile* infection; CFU, colony-forming unit; CHG, chlorhexidine gluconate; CLABSI, central-line–associated bloodstream infections; CP, contact precautions; CRE, carbapenem-resistant Enterobacteriaceae; EKG, electrocardiogram; EMR, electronic medical record; ERAS, early recovery after surgery; HAI, hospital-acquired infections; HCW, healthcare worker; HH, hand hygiene; HIV, human immunodeficiency virus; IBD, inflammatory bowel disease; IC, infection control; IP, infection prevention; IT, information technology; LOS, length of stay; MRI, magnetic resonance imaging; MRSA, methicillin-resistant *Staphylococcus aureus*; MSSA, methicillin-susceptible *Staphylococcus aureus*; NCI, noncritical items; NDP, nurse driven protocol; PFP, pay for performance; PPE, personal protective equipment; SARS, severe acute respiratory syndrome; SSI, surgical site infection; TSS, toxic shock syndrome; USD, universal staphylococcal decolonization;
UVC, ultraviolet C; VRE, vancomycin-resistant enterococci; WHO, World Health Organization.

Table 2. Descriptive Analysis of Studies Identified

Variables	Descriptive Statistics, No./Total (%)
Proportion of studies with learners	80/121 (70)
Proportion of studies that included learners as first or second authors	77/121 (64)
Case report	8/121 (7)
Single site	92/121 (76)
Perspectives/Editorials	21/121 (17)

In the absence of significant grant funding, the systematic assessment of infection prevention strategies and interventions requires a diverse, flexible, and highly collaborative environment. This process furthers the mentorship mission of academic medical centers. The mentor–mentee relationship is integral to the success of the learning hospital model. This partnership is frequently identified as a "symbiotic" relationship in which both parties have mutually agreed-upon goals with the expectation of gaining further knowledge.[20] Through educating the mentee, the mentor is able to enhance their expertise in the field. The mentee benefits through desired career guidance and outcomes.[21]

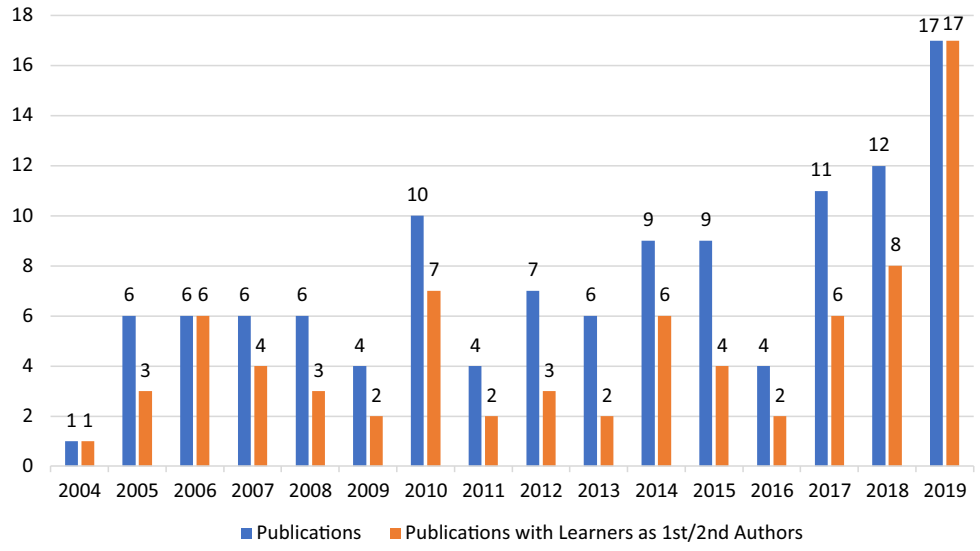

Fig. 1. Virginia Commonwealth University (VCU) Healthcare Infection Prevention Program (HIPP) publications with nonfaculty learners as first and/or second authors in relation to overall HIPP publications.

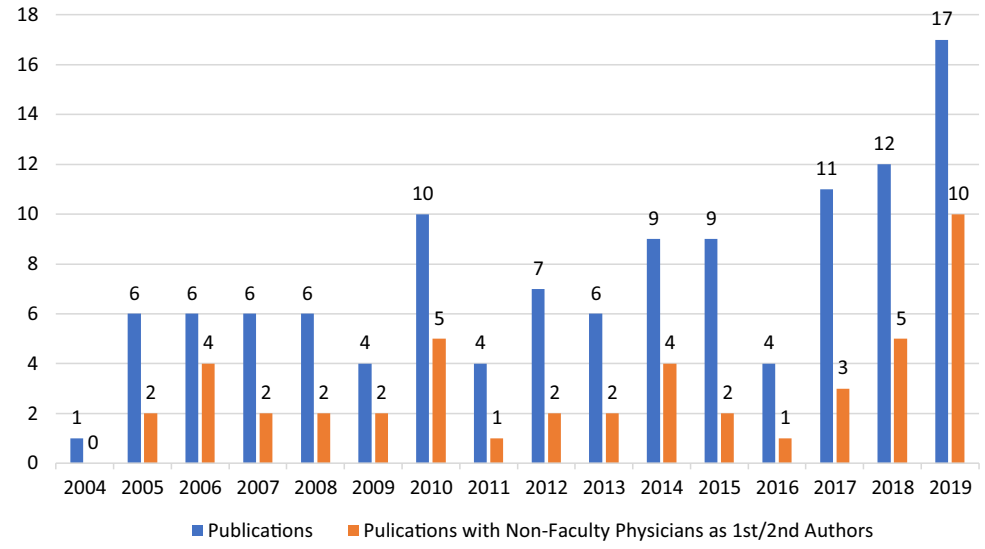

Fig. 2. Virginia Commonwealth University (VCU) Healthcare Infection Prevention Program (HIPP) publications with nonfaculty physicians as first and/or second authors in relation to overall HIPP publications.

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By providing mentorship and regular guidance with scheduled project follow-up, the energy, enthusiasm, data-gathering skills, and analytical capacities of nonfaculty learners are harnessed with the explicit purpose of preparing formal abstracts and manuscripts. Some research electives, particularly for medical students, are time limited to 8–10 weeks, requiring greater intensity of oversight.

With increased publication experience and evolving program visibility through novel perspectives in infection prevention, such as healthcare personnel attire and de-escalation of contact precautions for endemic pathogens, opportunities arise for collaborations and publications with colleagues outside of our institution.

Our learning hospital academic infection prevention model has several limitations. Despite the large roster of study collaborators, the minimal grant funding does not allow for long-term, multicenter projects with complicated methodologies and data collection designs. The preponderance of our work has included single center, quasi-experimental studies, observational studies, surveys, and interrupted time-series analyses, all with their inherent statistical and generalizability limitations. Many publications have been small in scope, with limited impact. Nevertheless, output of multiple small publications during the course of a career can result in a significant scholarly impact in toto.[22] Furthermore, our infection prevention program is optimally staffed and supported by our institution, with an associated school of medicine and infectious diseases training program that allows for greater opportunities to explore research topics relevant to our mission. These resources may not be uniformly available to all infection prevention programs.

We are the first to summarize the research experience of an academic infection prevention program under the framework of the learning hospital. Our research is largely focused on multiple aspects of a horizontal infection prevention strategy, antimicrobial stewardship, and controversial areas such as healthcare worker attire, bare below the elbows, and de-escalation of contact precautions for endemic pathogens. Our intent is to critically assess infection prevention strategies and to assess local perspectives and barriers to change policies and practices. The ongoing success of our research mission is based upon the synergy of the infection prevention physician epidemiologists, serving as leaders, mentors, and project managers with motivated college students, medical students, interns, residents, infectious diseases fellows, IP nurses, non-IP nurses, and non-IP HIPP staff. Similar models of diverse research collaboration, in addition to larger, grant-funded initiatives, are needed to further the science of infection prevention in an era of increased demands for healthcare safety.

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Conflicts of interest. There are no direct financial conflicts of interest in this study. However, there are nonfinancial conflicts of interest because this manuscript describes the success of the VCU HIPP program as a model example of a learning healthcare system, and the authors have developed, managed, and are employed by the program.

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