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REVIEW

# Strategies to Prevent Healthcare-Associated Infections: A Narrative Overview

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**Abstract:** Healthcare-associated infections (HCAIs) are a major source of morbidity and mortality and are the second most prevalent cause of death. Furthermore, it has been reported that for every one-hundred patients admitted to hospital, seven patients in high-income economies and ten in emerging and low-income economies acquire at least one type of HCAI. Currently, almost all pathogenic microorganisms have developed antimicrobial resistance, and few new antimicrobials are being developed and brought to market. The literature search for this narrative review was performed by searching bibliographic databases (including Google Scholar and PubMed) using the search terms: "Strategies," "Prevention," and "Healthcare-Associated Infections," followed by snowballing references cited by critical articles. We found that although hand hygiene is a centuries-old concept, it is still the primary strategy used around the world to prevent HCAIs. It forms one of a bundle of approaches used to clean and maintain a safe hospital environment and to stop the transmission of contagious and infectious microorganisms, including multidrug-resistant microbes. Finally, antibiotic stewardship also has a crucial role in reducing the impact of HCAIs through conserving currently available antimicrobials.

**Keywords:** prevention, hand hygiene, environmental hygiene, surveillance, antibiotic stewardship

## Introduction

Infectious and contagious diseases are of global concern and are the second most common cause of death in flora and fauna.[1] Communicable infectious diseases have threatened and challenged humans throughout history, where observers have recorded the advent of epidemics from epizootic diseases. Before communicable diseases were identified, infections were often attributed to various conditions: asters, environmental changes, acts of God, or spiritual reasons.[2–4] The notions of transmissible and spreadable diseases emerged first, and those of contagious and infectious diseases emerged much later.[5] In Europe between the 5th and the 15th centuries, contagious diseases had a substantial negative impact on public health.[5] From 1346–1353, plagues alone killed about 75 to 200 million of the European population, including the Bubonic plague known as the "Black Death."[6–9] Many European cities and towns were deserted as most of their communities died from the plague and other infectious diseases, with, for example, 300–400,000 people in Britain dying from the plague in one single outbreak in 1471.[10–13] Regular, but less severe, plague epidemics continued until 1650.[6] Before the discovery of antibiotics, average life expectancy was below 50 even for the people in high-income nations because of infectious diseases.[14] The dramatic rise in life expectancy in the 20th



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Century is primarily because of public health measures such as sanitation and the control of these diseases by antibiotics.[14] Although it was once thought that infectious diseases could be totally controlled, they are still a substantial public health problem around the world and, because they remain the primary cause of death and infirmity, the costs of treating them are both high and increasing.[15–21] At least 30 novel contagious and communicable diseases have appeared in the last 35 years, the majority of which are of zoonotic origin.[22] Over recent years, the socioeconomic, environmental, and ecological impact of infectious diseases has increasingly affected the huge mobile global population, which is encountering both new infections (such as COVID-19) and battling the worldwide epidemic of multidrug-resistant existing infectious diseases.[23–33] Currently, almost all pathogenic microorganisms have developed some antimicrobial resistance, and few new antimicrobials are being developed and brought to market.

Healthcare-associated infections (HCAIs) are a major source of morbidity and mortality and are the second most prevalent cause of death globally.[34–40] The World Health Organization (WHO) and other researchers report that 7% of patients in high-income economies and 10% in emerging and developing economies acquire at least one type of HCAIs, and of these patients, 10% die.[34–38] For example, in the US, approximately 1.7 million individuals develop HCAIs annually (a prevalence rate of 4.5%), causing the death of 90,000–99,000 people.[37,38] Another study found that 2,609,911 new cases of HCAIs were identified every year in the European Economic Area, causing 2,506,091 DALYs (Disability-Adjusted Life Years) per annum, corresponding to 501 DALYs per 100,000 of the population.[36–38] The prevalence rate of HCAIs in Lower- and Middle-Income Counties (LMICs) has been reported as between 5.7–19.1%.[38] However, data on HCAIs is patchy, particularly from LMICs because of more inadequate infrastructures (such as data record-keeping) and lack of resources.[38,41,42] The WHO conducted a multicenter study estimating HCAIs in Intensive Care Units (ICU), finding that 51% of patients admitted to ICUs developed HCAIs, which prolonged their hospital stay and increased the risk of further infections and other morbidities.[43] Infectious diseases cause 15 million deaths per year, of which 95% occur in the emerging economic nations, and these deaths are principally because of acute respiratory infections, diarrheal diseases, measles, AIDS, malaria, and tuberculosis.[1] Furthermore, it has been estimated that globally more than 1.4 million patients have HCAIs at any one time in both advanced and emergent countries, causing a substantial financial burden at an individual, community, and public levels.[44] A considerable proportion of HCAIs are, however, preventable through proper infection prevention and control (IPC) policy and planning.[38] This review presents current updates regarding global strategies to prevent healthcare-associated infections.

## Materials and Methods

The literature search for this narrative review was performed by searching bibliographic databases (including Google Scholar, and PubMed) (using free downloads as the research did not have financial support) provided by the Universiti Pertahanan Nasional Malaysia [(UPNM) the National Defence University of Malaysia], Kuala Lumpur, Malaysia and the University of the West Indies, St. Augustine, Trinidad, and Tobago. The search terms used were: "Strategies," "Prevention," "Hand Hygiene," "Environmental Hygiene," "Surveillance," "Antibiotic Stewardship," "Hospital Infections," and "Healthcare-Associated Infections" followed by snowballing references cited by critical articles. All types of peer-reviewed articles published in English were included. Articles for which the full text was not available and those not written in English were excluded. From the articles retrieved in the first round of search, additional references were identified by a manual search among the cited references. As this is a narrative (not a systematic) review, whilst we have included principally recent papers, those with historical relevance (which are older papers) to the narrative have also been included.

## Strategies to Prevent Healthcare-Associated Infections

HCAIs (their prevention and control) are a significant global public health burden about which concerns have been raised from all healthcare stakeholders, including health professionals, patients, and the public.[45–48] Their impact has dramatically increased because of the advent of multidrug-resistant pathogenic microorganisms.[49–51] Currently, almost all available antimicrobials are resistant[52,53] and very few antimicrobials are in the process of being developed for widespread use.[54–56] Amongst these pathogens, *Klebsiella pneumoniae*, which is the most common resistant pathogen, especially in ICU settings, is

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a significant concern.[57,58] The prevention and control of HCAIs is therefore very complicated, and a multi-dimensional approach and strategies are required to address this significant public health concern.[36,50,59–63]

In the following sections, we discuss the primary ways of addressing the impact of HCAIs as determined in the papers identified in the search and published in well-regarded journals[36,45–200] These are the main issues identified in these papers, noting that (depending on the focus of the research and findings) some articles report on a single issue, whereas others report on a number.

- Hand hygiene
- Maintaining a safe, clean, hygienic hospital environment
- Screening and categorizing patients into cohorts
- Public health surveillance
- Antibiotic stewardship
- Following patient safety guidelines

## Hand Hygiene

In the mid-19th Century, several researchers in Europe and the US, including Labarraque, Semmelweis, and Wendell Holmes, were working to prevent hospital-acquired, nosocomial HCAIs.[60,64–68] Although investigating independently, their observations led them to develop a similar hypothesis, ie, that health care workers (HCWs) carried pathogenic microorganisms from one patient to another on their hands, transmitting pathogens to vulnerable patients who consequently developed infections.[69] Over the next hundred years, much evidence accrued that pathogenic microorganisms were often transmitted through the hands of HCWs.[65,70–76] Semmelweis is regarded as the first doctor to identify the importance of hand hygiene (HH) in combating contagious infectious diseases.[77–80] Florence Nightingale, considered the founder of modern nursing practice,[81] wrote that "every nurse ought to be careful to wash her hands very frequently during the day … with soap and soft water"[82] subsequent to introducing handwashing and other hygiene practices in the war hospitals during the Crimean War (1853–1856).[83–85] HH practices were slow to become widespread; however, until much later, for example, it was only during the foodborne diseases outburst in the US in the 1980s that the Center for Disease Control and Prevention (CDC) recognized HH as a vital technique to stop the widespread infection.[74,86–88] Subsequently, the CDC produced and promoted guidelines regarding handwashing practices in hospitals, principally encouraging handwashing with non-antimicrobial soaps both before and after carrying out procedures with the possibility to spread pathogens, especially among high-risk patients, where they could rapidly cause a fatal outcome.[86–90] Alcohol-based solutions were suggested only in circumstances where a wash-hand basin was not accessible.[86,87] Another study in 1995 encouraged the use of antimicrobial soap or a waterless antiseptic agent for cleaning hands upon leaving the rooms of patients infected with multidrug-resistant microorganisms.[90]

Ensuring patient safety whilst in hospital and other healthcare facilities is a substantial international public health problem with HCAIs being the most common adverse events in any healthcare system in high- and low-income countries.[35,50,91] Each year, hundreds of millions of hospitalized patients are affected with HCAIs, causing substantial morbidity, mortality, and financial losses for individuals, communities, and the public healthcare budget.[92,93] HH has been identified as the most important single behavior change that healthcare workers can make for infection control, especially in relation to HCAIs.[59,94] For example, the strict practice of HH has been reported to reduce nosocomial infections by between 40% to 70%.[95,96] Despite this, rigorous hand washing strategies in hospitals have been observed to be weak, with multiple research studies reporting that globally, in many hospital wards, regular HH by healthcare workers often does not reach over 40%.[97–102] Non-compliance with the guiding principles of HH is thus a global public health issue which requires more standardized policies, regular monitoring and surveillance, and additional research.[102]

The Joint Commission Journal on Quality and Patient Safety reports 24 reasons HCWs cited for their non-compliance with effective HH.[103] Many reasons cited stem from a lack of education or training about the need for strict HH, leading to poor practice around ensuring and promoting HH as a key priority and a lack of understanding of how to maintain personal and patient safety. For example, some HCWs thought that wearing sterile gloves meant that HH was unnecessary or that their hospital management's requirements for HH were too extreme. This view was compounded by many hospitals lacking data and evidence about the impact of HH on infection rates. The high workload was cited as a key factor, with HCWs feeling overworked and burnt out and reporting a perceived lack of time to wash their hands properly or change their gloves between rooms/patients. HCWs also felt that in some clinical situations, such as emergency

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situations, HH could not be carried out properly, and specific issues were reported relating to gloving and gowning in isolation areas. Logistics and room design were reported as impacting non-compliance, for example, an inappropriate or troublesome location of a hand rub slot machine or basin; broken hand washing facilities, including lack of hand rub or cleanser or that the supplied cleansing agent caused irritation or allergy. The movement of colleagues and relatives between rooms, sharing of equipment, and lack of places to work or put equipment and paperwork were also cited as logistical problems leading to non-compliance with routine hand washing to stop the spread of cross-infection.[103]

Stemming from this study, the Joint Commission proposed five essential plans for improving HH, using the acronym 'HANDS': H = "Habit," A = "Active feedback," N = "No One Excused," D = "Data-driven," S = "Systems."[104] This plan aims to engender good HH habits in HCWs so that they wash their hands and maintain HH as an automatic behavior "upon entering or leaving a patient care area, as well as before and after patient care." Active feedback requires health professional leaders to continually remind their staff about HH importance and adherence. Health managers and administrative staff should provide an appraisal of and feedback on HCWs' HH practice with real-time performance data. Hospital authorities should regularly arrange necessary training programs and must acknowledge and reward hospital staff for achieving the targets. No one excused means that from the most senior to the most junior of all hospital staff, all are similarly accountable and responsible for appropriate HH hygiene. Hospital authorities should recognize HH as of paramount importance in maintaining patient care and safety, and every staff member must follow HH guidelines. Data-driven HH policy requires strict and routine monitoring and recording of compliance, with the data, gathered being analyzed to identify and prioritize areas for development and enhancement. Additionally, research should be continued to develop new ideas to resolve issues in implementing the best HH practice. Systems mean that HH responsiveness is a system-wide effort with rules and regulations regarding HH being applied throughout the health system. Authorities must provide all necessary logistic support to enable all workers to utilize, adhere to, and promote appropriate HH practice. This includes ensuring staff have easy access to HH facilities and using technologies to remind all workers to practice proper HH, emphasizing the benefits not only for patients but also for HCWs themselves.[104]

One recent systematic review comprising 14 articles concluded that a range of strategic methods is needed to raise HCWs' compliance regarding HH to an adequate level, but implementing all these might not be possible.[105] The interventions suggested included educational programs, monitoring, and feedback, ensuring logistics support, improving access to HH agents, and administrative support.[105] Another systematic review concluded that electronic and video monitoring systems could be very effective in enhancing HH practice and preventing or controlling HCAIs.[106] However, such methods are costly and may not be affordable for many hospitals, especially in low- and middle-income countries (LMICs). Besides, health professionals might not welcome such round the clock monitoring of their practice, and this could lead to strained professional relationships.[106]

In 2005, the WHO and World Alliance for Patient Safety started a movement, the First Global Patient Safety Challenge – "Clean Care is Safer Care" – aimed at improving HH in the healthcare system.[107] This campaign, known as WHO-5, encourages a multimodal plan comprising five different elements: "system change, training and education, observation and feedback, reminders in the hospital, and a hospital safety climate."[108] Currently, further strategies have been added based on behavioral sciences.[108] A systematic review and meta-analysis found that using the WHO-5 approach improved adherence to HH guidance among HCWs.[108] This study also suggests that hospital authorities should clearly set out their desired targets, those HCWs who meet the targets should be rewarded with financial incentives, and all HCWs, whatever their position, must be accountable. Such strategies lead to further improvements in HH practice. The study found that the resources and infrastructure required to report on the impact of intervention programs were often insufficient.[108] Another systematic review found that interventions to improve HH practice based on "knowledge, awareness, action control, and facilitation are not enough to change" HH practices.[109] This research additionally concluded that interventions should be combining diverse, innovative, creative strategies such as "social influence, attitude, self-efficacy, or intention" led to improvements. At present, most policy and planning aimed to ensure better compliance with HH guidance is targeted primarily at the individual and the institutional level, and "group- or team-directed" strategies are hardly ever used.[109] This

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research suggests that the inclusion of team-directed methods to improve HH would be more effective. This review concluded that more comprehensively designed planning is required that acknowledges the many challenges and barriers involved in changing HH practice and that this should address all levels: individual professional, team, and organization.[109]

Nurses are among the healthcare professionals who spend the most time on patient care and contact.[110] A systematic review and meta-analysis evaluating HH practice among nurses comprised six studies: three randomized controlled trials, one controlled before and after study, and two interrupted times series.[110] This report reflects the findings from other studies (e.g.,),[107] concluding that, whilst individual and collective intervention strategies could improve HH behavior among nurses, more impact was achieved when multimodal plans and policies were implemented.[110] This study also suggests setting targets, providing rewards such as bonuses, benefits or financial incentives, and supporting HCWs' individual accountability regardless of their administrative position.[108,110] Another systematic review comprising nineteen articles regarding HH knowledge and compliance among student nurses found a low level of knowledge and practice, with personal and administrative issues often influencing their HH knowledge and practice.[111] In summary, noncompliance with HH practice is a global public health issue that promotes more HCAIs, requiring more standardized multi-modal policies and the implementation of more research and monitoring.[102]

## COVID-19 and Hand Hygiene

Handwashing has regained substantial importance in the current global COVID-19 pandemic.[112,113] Whilst a very simple procedure, it is one of the most important protections against the transmission of disease-producing pathogens.[95,97,114,115] The CDC advises the public and health professionals to regularly wash their hands with ordinary soap and water for at least 20 seconds as it is considered the first-line preventive strategy of COVID-19 contamination. Alcohol-based hand sanitizers are recommended when soap and water are not accessible.[116,117] Multiple current research studies report that simple handwashing has prevented countless people and healthcare workers around the globe from acquiring COVID-19.[118–124]

## Environmental Hygiene

Maintaining strict environmental hygiene is an essential component of preventing and controlling infections, especially in HCAIs.[125,126] Infected and polluted hospital surfaces act as a key reservoir and source of transmission of life-threatening microorganisms, which include Clostridium difficile, antibiotic-resistant organisms such as methicillin-resistant Staphylococcus aureus (MRSA), and vancomycin-resistant enterococci (VRE).[127–129] Hospital surfaces, including both porous surfaces, eg, beds, mattresses and linen, and nonporous surfaces, eg, bed rails, door handles, call bells, and light switches are incredibly prone to microbial contamination with high-risk microbes.[126,130,131] Maintaining strict hygiene throughout hospitals is, therefore, essential in reducing HCAIs.[126,132,133] The aim of such environmental hygiene is to minimize the number of contagious microorganisms that commonly exist on surfaces, as the reduction of pathogens reduces the possibility of the transfer of infectious germs from object to person, thus reducing cross-infection.[134,135] Hospital cleaning is a complex and multi-layered process which involves the physical removal (utilizing detergents, chemical disinfectants, and water) of contagious and infectious material from all types of surface, including sputum, urine, blood, secretions, excretions, microorganisms and dust, that can nourish the growth of microorganisms.[136–141]

The US Center for Disease Control and Prevention (CDC) and the Healthcare Infection Control Practices Advisory Committee endorses that infection prevention and control is the most urgent and vital issue wherever medical care is provided to individuals or communities, irrespective of the type or size of the organization and the healthcare provided.[142,143] Appropriate safety measures should include a routine, deep cleaning of all areas of the hospital, both in-patient and out-patient, to minimize communicable transmission infectious diseases.[142,143] Antimicrobials used for hospital cleaning comprise both single or multiple components aimed to extinguish or arrest the growth of infectious disease-producing microorganisms, including bacteria, viruses, or fungi. Hospital cleansing products may contain about 275 different constituents and are available in various formulations such as sprays, liquids, concentrated powders, and gases.[144] It is crucial for users to understand the level and type of cleaning, its purpose, and limitations, including the various terms, definitions, and classification used (eg, sterilization, disinfection, cleaning) and the categorization of devices and surfaces that require specific measures.[145,146] Ethylene oxide gas is used for sterilization, which aims to kill all microorganisms.[146–148] Disinfection can eliminate nearly all metabolically active microorganisms except for all microbial spores[149] Hydrogen peroxide (7.5%) is

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a common agent utilized for high-level disinfection.[86,87,146] Isopropyl alcohols with a concentration of 70–90% can provide intermediate-level disinfection by the eradication of all vegetative microorganisms with a small number of bacterial spores.[146] A quaternary ammonium microbial detergent solution can achieve low-level disinfection by eradicating most metabolically active bacteria, some fungi, and viruses but not metabolically inactive spores.[86,146] Cleaning is described as the removal of soil, dust, earth, or biological pollution from an instrument or hospital physical surface through brushing, scrubbing or scraping, using detergent, the surfactant or emulsifying agents that reduce surface tension, and water. Cleaning eliminates many contagious microbes from hospital surfaces, thereby reducing the bacterial load on surfaces. Cleaning is, therefore, the first stage of maintaining hospital hygiene, particularly for surfaces having evident pollution, and helps to safeguard the success of subsequent disinfection procedures.[145]

## Screening and Cohorting Patients

There is increasing political and community concern because multiple approaches have failed or struggled to control the spread of HCAIs, resulting in high morbidity and mortality due to AMR infections developed during hospital stays.[150–155] Strategies aimed at minimizing and controlling HCAIs comprise active surveillance cultures (ASCs), contact isolation of patients colonized with epidemiologically significant pathogens, and pre-emptive isolation of high-risk patients.[156]

It has been suggested that ASCs of all or certain high-risk patients and placing them under contact precautions will help to curb or eliminate the multidrug-resistant organisms (MDROs) that can trigger HCAIs.[157] Implementing ASCs is not straightforward, however, raising ethical issues around conflict of interests and confidentiality, practical issues around logistics and bed management, which may lead to isolating or segregating patients when they did not need to be, reallocation of budgets to manage the potentially infected patients, and reduction of healthcare output. ASCs can particularly affect workload in emergency rooms and the ambulance service. Considering these issues, some researchers concluded that implementing ASCs needs to be based on accurate assessments of the impact on public health, and the costs and benefits in relation to existing prevention and control measures.[158] A systematic review comprising twenty articles found that although ASCs have been recommended for different hospitals to control the increasing numbers of infections due to multidrug-resistant organisms, their effectiveness and cost-effectiveness are not proven.[159] Another prospective study identified that ASCs conducted on patients admitted to ICU did not find the microbes causing bacteriological diseases with the most severe consequences and that bloodstream infections might not, therefore, be associated with ASCs.[160] Again, in the ICU setting, a study carried out for four years found that management of MRSA in the ICU does not require ASCs.[161]

Several countries have successfully reduced the intensities of MRSA infections by executing countrywide controlling strategies such as "search and destroy" (S&D).[162] Measures of S&D include the segregation of MRSA-positive patients; anticipatory separation and assessment and evaluation of high-risk cases; screening of patients and staff after an unexpected case of MRSA; assessment of HCWs who are on leave as potential carriers; total decontamination where required and stopping new admissions in areas where more than one carrier found amongst hospitalized patients.[163] MDR pathogens such as MRSA, VRE, and multidrug-resistant Gram-negative bacilli (MDR-GNB) are often found in many hospitals and healthcare settings and act as a potential source of MDR outbreaks.[164–166] One earlier study reported that approaches to the transmission of HCAIs "include contact isolation, cohorting care, maintaining appropriate staffing ratios, use of active microbiologic surveillance, and decreasing hospital stays."[163] Multiple studies suggested that patient isolation, ASCs, and staff screening can decrease the transmission of MDR pathogens.[164,167] And finally, another study found that the anticipatory use of sterile "gloves, with or without a gown," especially among patients with a high risk of carrying contagious diseases, were very effective in the management of an outbreak of MDRs.[168]

## Surveillance

Public health surveillance is defined as the ongoing systematic collection, analysis, interpretation, and dissemination of data regarding a health-related event for use in public health action to reduce morbidity and mortality and to improve health.[169] Surveillance data regarding HCAIs can be used to assess the extent, escalation, and status of infections, to examine, scan and monitor trends of infection rates, inform alert programs, and improve performances, strategy and competence development.[170,171] One Scottish study suggested that because the surveillance

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system in Scotland was not so well-organized, the time taken to first recognize HCAIs was longer than the gold standard.[172] This study also found that the time at which HCAIs are recognized can be reduced either by "increasing the number of hospitals participating in surveillance or by optimally selecting which hospitals to include in a surveillance system."[172] Two other Scottish studies echoed this, reporting that a better surveillance system could have prevented a considerable number of *Staphylococcus aureus* bacteremia (SAB) episodes.[173,174] One recent Indian observational prospective study noted a low incidence of HCAIs due to the strict practice of active surveillance in a neurosurgery unit.[175] In Germany, the Krankenhaus Infections Surveillance System (KISS) was found to decrease HCAIs more efficiently in comparison to other protocols.[176] This system is like that described by the CDC and is structured like the National Nosocomial Surveillance system of the USA.[177,178] However, another German study reported that the KISS surveillance system tended to miscalculate the rates of HCAIs.[179] Later, yet another German study reported that around 35% of ICUs in Germany have never isolated patients with MRSA as individuals or cohorts.[180] Isolation of MDRs infected patients is one of the top priority issues in preventing or controlling an HCAIs epidemic.[140,181,182] The timely recognition of the unique variants of HCAIs, especially of MDRs pathogenic microorganisms, is vital, although surveillance strategies are frequently restricted because of financial and practical limitations. Therefore, although surveillance is extensively acknowledged as playing an active part in preventing and controlling HCAIs, there is not enough evidence on how well-organized individual healthcare centered surveillance structures work and how lessons can be applied in low resource settings.[183]

## Antibiotic Stewardship

The term Antimicrobial Stewardship (AS) was first coined by McGowan and Gerding in 1996.[184] They highlighted that physicians and other health professionals must see antimicrobials as a very valuable one-time healthcare resource.[183] The Society for Healthcare Epidemiology of America defines Antibiotic Stewardship as a set of coordinated strategies to improve the use of antimicrobial medications with the goal of enhancing patient health outcomes, reducing resistance to antibiotics, and decreasing unnecessary costs.[185] AS is also described as the optimal selection, dosage, and duration of antimicrobial treatment that results in the best clinical outcome for the treatment or prevention of infection, with minimal toxicity to the patient and minimal impact on subsequent resistance.[186] As promotes the prudent and rational use of antimicrobials and helps avoid excessively or in appropriate use.[187]

> Hey, surgeons! It is time to lead and be a champion in preventing and managing surgical infections![188]

The World Society of Emergency Surgery (WSES) states that surgeons should take the lead in infection prevention, policy, planning, and implementation. WSES has developed several guidelines for infection prevention, particularly for surgery-related issues, aimed at improving health outcomes in relation to surgical infection-related management.[188–191] Scientists at Tufts Medical Center suggest that whilst AMR is increasing globally, the development of new antibiotics has slowed, and therefore, the conservation of antimicrobials is essential.[192] The CDC describes the seven core elements of AS as "leadership commitment, accountability, drug expertise, action, tracking, reporting, and education."[193] The three primary objectives of AS are first, to ensure prudent and rational utilization of antimicrobials with precisely targeted doses of the right antibiotic, the "de-escalation to pathogen-directed therapy," and to deliver antibiotic therapy to an agreed, precise timeframe.[192,194] The second objective is the need to halt overall antimicrobial overuse, misuse, and abuse in both community and in-patient hospital facilities, and the third are to halt or slow the expansion of resistance.[192]

The two most important methods of approach to AS are described, with the most effective initiatives combining both approaches.[192] The first method of stewardship is in restraining "prescriptive authority." Clinicians should be restricted from prescribing specific antimicrobials, and they should be required to seek prior approval for prescribing such antimicrobials.[192] The second method bases treatment on laboratory reports of culture sensitivity tests, not just clinical signs and symptoms, to ensure that the antibiotic prescribed (if any) is appropriate. Only then should these antibiotics be made available to physicians with guidance that antibiotic availability and treatment might be adjusted, or even suspended.[192] Multiple research studies report that the combination of these approaches reduced antimicrobial prescribing and led to higher satisfaction about the quality of care in both doctors and patients.[195,196] A systematic review and meta-analysis recently reported that AS initiatives have specifically decreased the frequency of infectious diseases and

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"colonization with antibiotic-resistant bacteria and Clostridium difficile infections in hospital inpatients."[197] These reports provide healthcare professionals and policy-makers "with evidence for the implementation of antibiotic stewardship interventions to reduce the burden of infections from antibiotic-resistant bacteria."[197] One prospective appraisal of 176 ASP interventions reported a significantly reduced antimicrobial use of 24.3%. It concluded that this had a very positive impact on overall antimicrobial usage, length of therapy, and length of in-hospital stay.[198] One quasi-experimental retrospective analysis found that the introduction of ASP was associated with a decrease in antibiotic use as well as overall healthcare costs, with a significant reduction in the incidence of some microbes.[199] Another systematic review showed that the implementation of hospital ASPs made significant improvements in infection rates and clinical outcomes as well as financial savings.[200] Furthermore, another systematic review and meta-analysis found that ASPs in hospitalized patients in the Asia Pacific region effectively reduced antimicrobial use, and improved patient's treatment outcomes.[201] One additional study reported that improved ASP is essential to stop or limit the emergence of AMR, lengthen the efficacy of available antimicrobials, provide better healthcare outcomes and reduce the healthcare costs of HCAIs for both individuals and communities.[202] Another study described three different strategies to control antimicrobial resistance: infection prevention and control, diagnostic stewardship, and antimicrobial stewardship.[203]

## Following Patient Safety Guidelines

Policies, guidelines, and checklists are an essential part of improving patient safety; however, these are often interpreted and implemented differently by individuals, departments, and organizations, based on local influences and practices and often not taken behavioral science into account.[204–206] A study investigating the failure of an HCAIs strategy found low levels of physician engagement and compliance with guidelines and policies.[207,208] Even in healthcare facilities where policies, guidelines, and checklists were effectively implemented, doctors and other health professionals' practices were found to degrade after around one year. The reasons given included: too much information being provided; guidelines being too complicated to implement; that guidelines conflicted with other guidelines, and because little evidence was provided to support the guidance.[209,210]

All healthcare policies and planning around patient safety must embed the prevention and control of HCAIs as a fundamental principle.[36,206,211,212] As mentioned earlier, the control and prevention of HCAIs is best achieved through a broad, integrated approach and cooperation between healthcare facilities, public health authorities, health insurances, quality management, and patient safety organizations, educational facilities, the public, and the veterinarian sector.[213] Another study regarding the improvement of patient safety identified that the following measures helped to optimize the impact of a program: ensure that the educational program is introduced well and certified; report the program outcomes publicly; carefully design healthcare settings with patient safety in mind; promote an informed and transparent managerial approach; provide clear guidance and role modeling; facilitate collaboration between the healthcare program and government health institution; reduce hospital overcapacity; ensure accountability, and provide financial support.[214]

## Strategies for the Prevention of COVID-19

In order to combat the COVID-19 crisis, health systems leaders around the world have had to adopt rapid multiple lines of attack to appraise critical requirements and address areas of weakness.[215] This includes taking a rigorous approach to reduce the rates of COVID-19 infection, hospitalization, morbidity, and mortality.[216,217] The appropriate strategy for preparedness to face COVID-19 or any future pandemic must be based on reputable guidelines, protocols, and direct experiences of those working on the front line during the COVID-19 pandemic.[216,218] The foundations of an operational COVID-19 preventive vigilance and action plan include: 1) mitigating local transmission; 2) conserving, supporting, and protecting staff; 3) eliminating non-urgent strains on the system and 4) coordinating communication.[216] Because hospitals and clinics are considered as core areas for the transmission of COVID-19,[219] three principal measures should be implemented to reduce preventable exposure and transmission of COVID-19: 1) restrict both visitors and other non-COVID-19 patients to the health care facility; 2) specific healthcare workers need to work in the COVID-19 zone; and 3) every person must be screened and tested regularly before and after entering the hospital facility.[216,219,220]

## Limitations of the Study

This is a narrative review and not a systematic review, so it is not all-inclusive. Plus, the topic of strategies to prevent

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HCAIs is extremely broad, and therefore it has not been possible to include all discussions relating to the prevention and control of HCAIs in a single manuscript; therefore, the authors have focused on identifying the most significant features of the current debate.

## Conclusions

HCAIs are an increasingly important and severe public health issue about which concerns have been expressed among all stakeholders involved in healthcare, including doctors, nurses, allied health professionals, patients, and the public.[45–48,221] Globally, the prevention and control of HCAIs have become an urgent issue, particularly because of the rise of multidrug-resistant pathogenic microorganisms.[49–51] This research study found overwhelmingly that hand and environmental hygiene with antibiotic stewardship are the principal measures that minimize HCAIs and improve treatment outcomes.

## Recommendations

Determined actions are required to address the burden of healthcare-associated infections worldwide and improve patient safety. Hand hygiene and the prudent use of antimicrobials are the key strategies in preventing HCAIs. Hand hygiene is the leading measure for preventing the spread of antimicrobial resistance and reducing HCAIs. Hand hygiene can prevent a significant number of HCAIs since healthcare workers' hands are the most common vehicle for the transmission of healthcare-associated pathogens from patient to patient and within the healthcare environment. Available evidence highlights the fact that multimodal intervention strategies lead to improved hand hygiene and a reduction in HCAIs. The introduction of alcohol-based hand rubs and continuous educational programs are key factors to overcome infrastructure barriers and to build robust knowledge improvement. Antimicrobial stewardship is also vital to optimize the use of antimicrobials to prevent the development of resistance and improve patient outcomes. Coordinated strategies are required between all actors in the system to help prevent antimicrobial resistance.

## Key Findings

- HCAIs are the leading cause of morbidity and mortality worldwide, and most of them are preventable.
- Hand hygiene is the most effective, simplest, and cheapest measure to prevent HCAIs, but compliance with hand hygiene remains low amongst HCWs.
- In order to improve hand hygiene compliance among HCWs, intervention strategies should be implemented, and standardized measures for monitoring should be put in place.
- Ensuring adequate hospital environmental hygiene is essential for reducing the threat of HCAIs by minimizing the number of contagious microorganisms existing on surfaces and reducing cross-infection.
- The cost-effectiveness of active surveillance cultures (ASCs) is not proven. Contact isolation of patients colonized or infected by pathogens can decrease the transmission of drug-resistant organisms.
- Active and passive surveillance programs should be implemented to assess and monitor the extent and trends of HCAIs, to develop precautionary programs, and improve performance, strategy, and competence development.
- The implementation of Antibiotic Stewardship Programs is vital to enhance patient health outcomes, reduce resistance to antibiotics, and decrease unnecessary costs.
- Guidelines are an important tool to improve patient safety, and efforts should be put into action to improve HCWs adherence to them.
- Extensive integrated approaches involving cooperation between public health authorities and HCWs are needed to maximize patient safety by preventing HCAIs.

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## Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis, and interpretation, or in all these areas; took part in drafting, revising or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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