Infection Prevention and Control

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9.1 Introduction

A healthcare-associated infection (HAI) is defined as: "An infection occurring in a patient during the process of care in a hospital or other health-care facility which was not present or incubating at the time of admission. This includes infections acquired in the hospital, but appearing after discharge, and also occupational infections among staff of the facility" [1]. The term "healthcare associated" has replaced the former ones used to refer to such infections (i.e., "nosocomial" or "hospital"), as evidence has shown that HAIs can occur as a result of the provision of healthcare in any setting. While the specific risks may differ, the basic principles of infection prevention and control apply regardless of the setting [2].

HAIs are one of the most common adverse events in care delivery and pose a major public health problem impacting morbidity, mortality, and quality of life. At any one time, up to 7% of patients in developed countries and 10% of patients in developing countries will be affected by at least one HAI [3]. These infections also represent a significant economic burden at the societal level, accounting for a considerable proportion of costs; for example, in 2006, the mean excess cost of HAIs in Belgium was close to 6% of public hospital spending, while in the UK it was 2.6% [4]. The estimated cumulative burden in disability-adjusted lost years (DALY) of the six top HAIs is twice the collective burden of 32 other communicable diseases (501 DALYs versus 260 DALYs) [5].

9.2 Main Healthcare-Associated Infection

The main HAIs are generally distributed anatomically as follows: 35% involve the urinary tract, 25% the surgical site, 10% the lungs, 10% the bloodstream. The remaining 10% involve other sites [6].

9.2.1 Urinary Tract Infections (UTIs)

Urinary tract infections are the most common HAIs and most patients with healthcare-

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associated UTIs have either undergone genitourinary or urological manipulation (10–20%) or permanent urethral catheterization (around 80%), or both. Infections are usually defined by microbiological criteria: positive quantitative urine culture ($\geq 10^5$ microorganisms/ml, with a maximum of two isolated microbial species). Morbidity and mortality from UTIs are low compared to other HAIs, but they can sometimes lead to bacteremia and death [1]. The high prevalence of urinary catheter use—between 15% and 25% of hospitalized patients may receive short-term indwelling urinary catheters—leads to a large cumulative number of infections and resulting complications and deaths. The source of microorganisms causing UTIs can be endogenous (as in most cases) or exogenous, such as via contaminated equipment or via the hands of healthcare staff. Microbial pathogens can enter the urinary tract of catheterized patient either via migration along the outside of the catheter in the periurethral mucous sheath or via movement along the internal lumen of the catheter from a contaminated collection bag or catheter-drainage tube junction. The most frequently associated pathogens are *Escherichia coli*, *Pseudomonas*, *Enterococcus*, *Klebsiella*, *Enterobacter*, and *Proteus*. Multivariate analyses have underlined that the duration of catheterization is the most important risk factor in the development of catheter-associated bacteriuria. Other risk factors include colonization of the drainage bag, diabetes mellitus, female gender, poor quality of catheter care [7].

Antimicrobial resistance of urinary pathogens is an increasing problem; in Europe, *Escherichia coli* is reported to be resistant to fluoroquinolones in 8–48% of the isolates and to third-generation cephalosporins in 3–82%, and *Klebsiella pneumoniae* is reported to be resistant to third-generation cephalosporins in 2–82% of the isolates and to carbapenems in 0–68% [8].

9.2.2 Bloodstream Infections (BSIs)

Bloodstream infections represent a smaller proportion of HAIs, but the associated case fatality rate is high [1]: 25–30% of patients with healthcare-associated bloodstream infections die, and the attributable mortality is at least 15% [6]. They also influence the length of stay and costs [9]. The incidence is increasing, particularly for certain organisms such as multiresistant coagulase-negative *Staphylococcus*, *Enterobacteriales*, and *Candida* spp.

The Surveillance and Control of Pathogens of Epidemiologic Importance (SCOPE) project surveillance system showed that 70% of all healthcare-associated bloodstream infections are associated with a central venous catheter [6]. Infections may occur at the skin entry site of the intravascular device or in the subcutaneous path of the catheter. Organisms colonizing the catheter within the vessel may produce bacteremia without visible external infection. The cutaneous flora, whether resident or transient, is the source of infection. The main risk factors are length of catheterization, level of asepsis at insertion, and continuing catheter care [1]. The leading causes of healthcare-associated bloodstream infections are coagulase-negative staphylococci, *Staphylococcus aureus*, enterococci, and Candida species. More than 90% of coagulase-negative staphylococci and 60% of *S. aureus* isolates are resistant to methicillin, more than 30% of enterococci to vancomycin, and more than 10% of Candida organisms to first-generation triazoles [6]. Large and sustained reduction (up to 66%) in rates of catheter-related bloodstream infections has been obtained by implementing procedures recommended to reduce BSIs, such as hand washing, using full-barrier precautions during the insertion of central venous catheters, cleaning the skin with chlorhexidine, avoiding the femoral site if possible, and removing unnecessary catheters [10].

9.2.3 Surgical Site Infections

Surgical site infections (SSI) are infections occurring in the incision site or in deep tissues where surgery has been performed, within 30 days of surgery or longer if a prosthetic device has been implanted. SSIs are one of the most frequent healthcare-associated infections, account-

ing for about 20–25% of all HAIs and about 38% of the HAIs in surgical patients, with an incidence up to 19%, depending on the kind of surgery [11–13]. SSIs may involve the superficial or deep layers of the incision (in two thirds of cases), or the organ or area manipulated or traumatized (in one third of cases) [14]. SSIs can range from wound discharge to a life-threatening condition and they are associated with considerable morbidity. SSIs lead to an increase in the length of hospital stay by 3.3–32.5 days and patients are twice as likely to die, twice as likely to spend time in intensive care, and five times more likely to be re-admitted after discharge. Healthcare costs increase substantially for patients with SSI [15–20].

Factors influencing the potential for infection include endogenous (patient-related) and exogenous (process/procedural-related) variables. Related patient characteristics include extremes of age, poor nutritional status, obesity (i.e., more than 20% above the ideal body weight), coincident remote site infections or colonization, diabetes, and cigarette smoking. Process/procedural-related variables include surgical procedure classification (e.g., "contaminated" or "dirty"), length of surgery, and type of postoperative incision care [14, 21].

An independent risk factor for some postoperative infections is failure in the administration of perioperative antibiotic prophylaxis when indicated. Incorrect timing of surgical prophylaxis is associated with increases by a factor of 2–6 in the rates of surgical site infection for operative procedures in which prophylaxis is generally recommended [11].

Practices to prevent SSIs aim to minimize the number of microorganisms introduced into the operative site or enhance the patient's defenses against infection.

9.2.4 Healthcare-Associated Pneumonia

Healthcare-associated pneumonia occurs in various patient groups. The most important group is that of patients on ventilators in intensive care units (ICU) [1], where the rate of pneumonia, the main type of infection, is a quality and safety indicator of care [22]. There is a high case fatality rate related to ventilator-associated pneumonia (VAP) although the attributable risk is difficult to determine because of the high patient comorbidity. The microorganisms involved are often endogenous (e.g., from the digestive system or upper respiratory tract), but may be exogenous, often from contaminated respiratory equipment. Known risk factors for infection include type and duration of ventilation, quality of respiratory care, severity of patient's condition (e.g., organ failure), and any previous use of antibiotics [1].

A recent meta-analysis of randomized and non-randomized studies published before June 2017 employed VAP prevention bundles and reported on their effect on mortality; the meta-analysis found that "simple interventions in common clinical practice applied in a coordinated way as a part of a bundle care are effective in reducing mortality in ventilated ICU patients" [23].

9.3 Antimicrobial Resistance

While there has been progress in the struggle against HAIs over time, antimicrobial resistance has become one of the greatest challenges of the twenty-first century and a cause for global concern due to its current and potential impact on global health and the costs to healthcare systems. Recent reports suggest that absolute numbers of infections due to resistant microbes are increasing globally [24].

Multidrug-resistant organisms (MDRO), which are predominantly bacteria, are resistant to multiple classes of antimicrobial agents. Antimicrobial resistance increases the morbidity and mortality associated with infections and increases costs of care because of prolonged hospitalization and other factors such as a need for more expensive drugs. A major cause of antimicrobial resistance is the exposure of a high-density, high-acuity patient population in frequent contact with healthcare workers to extensive anti-

microbial use, along with the related risk of cross-infection.

The main MDROs are methicillin-resistant *Staphylococcus aureus* (MRSA), which are responsible for up to a third of healthcare-associated bloodstream infections, vancomycin-resistant enterococci (VREs) with mobile resistance determinants (e.g., VanA and VanB), and a range of Gram-bacteria (MDRGNs) with multiple classes of drug resistance to or resistant mechanisms against critically important antimicrobials. Highly transmissible resistance is a particular feature of Gram-bacteria, especially Enterobacteriaceae; several strains of Gram-bacteria (e.g., *Pseudomonas aeruginosa* and *Acinetobacter baumannii*) have now been identified that exhibit resistance to essentially all commonly used antimicrobials. These organisms are associated with treatment failure and increased morbidity [2].

While bacteria develop resistance to commonly used antibiotics, the number of new antibiotics introduced into the market is small as this class of medicine is not as profitable for pharmaceutical industries as medications for chronic disease. Moreover, the bacteria's capacity to develop resistance makes new antibiotics obsolete early after marketing and consequently causes their development to be even less profitable [25].

With the increase in antimicrobial resistance, progress in modern medicine, which relies on the availability of effective antibacterial drugs, is now at risk, and the expectation is that medicine will be increasingly unable to treat infections currently considered to be routine.

9.4 Healthcare-Associated Infection Prevention

Traditionally, healthcare-associated infections have been considered a "stand-alone" problem and specific professional profiles have been developed as well as legislation and policies aimed at infection prevention and control (ICP).

Core competencies (i.e., competencies that should be a minimum prerequisite for all professionals in this field) have been defined by the European Centre for Disease Prevention and Control (ECDC) for infection control and hospital hygiene professionals [26] matching the profile of a medical doctor (an ICP practitioner) or a nurse (an ICP nurse) working in Europe. Competencies are grouped into domains which are in turn grouped into four areas: program management, quality improvement, surveillance and investigation of healthcare-associated infections, and infection control activities.

In Italy, central regulation about infection control has for years been based on just two documents issued by the Ministry of Health, one in 1985 (*Fighting against Hospital Infection*) [27] and the other in 1988 (*Fighting against Hospital Infection: the surveillance*) [28]; so, at the local level, policies have varied.

In all the European Region, decisions about infection prevention and control have often been made at the institutional level, with or without national or continental recommendations in mind, with available resources and dominant clinical cultures playing a pivotal role [29].

The large number of international guidelines targeting specific healthcare-associated infections that have been proposed over time by different agencies has resulted in varying applications and outcomes.

In particular, the WHO has provided "WHO Guidelines on Hand Hygiene in Health Care" [30], "Global Guidelines for the Prevention of Surgical Site Infection" [31], and "Guidelines for the prevention and control of carbapenem-resistant Enterobacteriaceae, *Acinetobacter baumannii* and *Pseudomonas aeruginosa* in health care facilities" [32].

In the EU, things changed with the "Council Recommendation of 9 June 2009 on patient safety, including the prevention and control of healthcare associated infections" [33] in which HAIs were covered as a safety problem. The recommendation provides guidance on patient empowerment and promotes a culture of patient safety. In terms of HAI-related actions, it states that member states should use case definitions agreed upon at the EU level to allow consistent reporting; European case definitions for reporting

communicable diseases were updated in 2012 [34]. The council recommendation triggered the development of national strategies and reporting and learning systems in many member states. The ECDC network for the surveillance of healthcare-associated infections (HAI-Net) supports member states in establishing or strengthening active surveillance systems. Decisions made at the level of the EU contributed to the improvement of HAI surveillance systems through the adoption of a common, specific case definition for HAI and a framework for national surveillance.

The 2011 Cross-border Patients' Rights Directive [35] highlights the importance of transparency and provides guidelines for setting up national contact points for the diffusion of information about care standards, taking into account advances in medical science and good medical practices.

In fact, HAIs are recognized as part of the safety problems for patients and thus they should be addressed.

The ECRI Institute's "Top 10 Patient Safety Concerns" is a list released in 2019 identifying top-priority safety concerns such as newly identified risks, existing concerns that have changed due to developments in technology or new care delivery models, and persistent issues that need focused attention or present new opportunities for intervention. Unsurprisingly, the list includes three infection-related issues: "Antimicrobial Stewardship in Physician Practices and Aging Services," "Early Recognition of Sepsis across the Continuum," and "Infections from Peripherally Inserted IV Lines" [36].

In 2016, the WHO issued international, evidence-based guidelines regarding the core components of IPC programs [3]. The guidelines were developed by international experts to prevent HAIs and combat antimicrobial resistance, while taking into account the strength of available scientific evidence, the impact on cost and resources, as well as patient values and preferences. The guidelines provide a framework for implementing or developing IPC programs, applicable to any country and adaptable to local context, available resources, and public health needs.

9.4.1 The Prevention and Control of Healthcare-Associated Infection: A Challenge for Clinical Risk Management

Guidelines for tackling HAIs uniformly address the issue with a systemic approach. A systemic approach reframes IPC endeavors as components of a wider and more complex system which manages patient safety and quality of care [37].

Individually reliable components may generate unsafe outcomes when interacting within the system as a whole, even if they are functioning appropriately. A proper surgical intervention or evidence-based antiblastic therapy may be undermined by IPC that is not effective throughout the care continuum.

Consequently, safety is an emergent property of the system, not dependent on the reliability of the individual components but on the management of the interactions between every part of the system, including people, devices, processes, and administrative control [38].

Multiple studies indicate that the most common types of adverse events affecting hospitalized patients are adverse drug events, HAIs, and surgical complications [39].

HAIs are unintended, unwelcome consequences of healthcare that, if serious, can have dreadful effects, and are often similar to other adverse events, in that they can prolong the length of stay, cause harm to the patient, and are preventable to a large extent.

Notwithstanding the fact that HAIs are injuries related to management of care processes rather than complications of disease [40], healthcare workers perceive HAIs differently from adverse events. When not discussed further or brought under a higher level of scrutiny—even if they are reported to the patient and the family—HAIs will be probably presented as complications of care and not as preventable events.

It has been proposed that this difference in approach toward HAIs originates from factors such as the widespread belief that antibiotics can solve infection-related problems, the weakness of evidence supporting HAI-preventing interventions, the sense of responsibility felt by health-

care staff, and the perceived intractability of the problem [25].

With this mindset, HAIs pose a significant challenge to the way in which clinical risk management is deployed in healthcare systems.

The International Classification for Patient Safety taxonomy (ICPS) [41] aids in the detection of failures, contributing factors, and near misses within an incident analysis framework. Learning and reporting systems are based on "lagging" indicators [41] as they refer to the post hoc detection of critical occurrences and aim to enhance incident detection capability and the potential to learn from failures. Consequently, these systems are very unlikely to detect the risks posed to patient safety by HAIs. Since they are designed to be event-focused rather than hazard-based, learning and reporting systems are fed with only events that have already occurred for subsequent identification and analysis. Moreover, the preconditions for HAIs to occur are products of a silent behavior occurring most of the time when the patients are not "on-board" of healthcare processes. While both the active failure (i.e., the point of error) and the latent failure (i.e., the origin of error) are often easy to identify, in the case of an adverse event, the scene changes completely when an HAI is involved. Even with an understanding of bacterial spread, it is most often difficult to identify the source of a particular HAI within a healthcare organization, and so healthcare professionals have the tendency to view the problem as ineluctable. However, HAIs and other types of adverse events often happen due to the recurrence of similar circumstances. Therefore, in order to improve safety, clinicians and managers need to look more carefully at the context, and apply the lessons learnt.

Risk management is about reducing the probability of negative patient outcomes or adverse events by systematically assessing, reviewing, and then seeking ways to prevent, occurrence. Fundamentally, risk management involves clinicians, managers, and healthcare providers in identifying the conditions surrounding practice that put patients at risk of harm and in acting to prevent and control these circumstances to manage and reduce risks [42].

Successful approaches for preventing and reducing HAIs involve applying a risk management framework to manage both the human and systemic factors associated with the transmission of infectious agents. This approach ensures that infectious agents, whether common (e.g., gastrointestinal viruses) or evolving (e.g., influenza or multiresistant organisms), can be managed effectively [2].

Involving patients and their carers is essential for the successful prevention of infection and control in clinical care. Patients need to be sufficiently informed to be able to participate in reducing the risk of transmission of infectious agents.

Although infection prevention specialists (IPs) have long assessed risks related to populations served, services provided, surveillance data, and outbreaks, and lapses in desired practices, new accreditation standards, and rules require that risk assessment and goal-setting should be systematic for an effective approach to infection prevention and control.

Risk assessment and goal-setting need to form a more structured, formal process to enhance a well-designed and thoughtful approach to infection prevention. In the case of HAIs, it may be misleading to place the emphasis solely on the reporting of adverse events and the detection of near misses. In order to fruitfully integrate clinical risk management and IPC, surveillance must be merged with an epidemiological approach within a risk assessment framework.

Risk is defined as the combination of the probability of occurrence of a hazard generating harm in a given scenario and the severity of that harm. Risk is therefore contextual and can only be assessed with respect to a given scenario. Pragmatically, risk is the interaction between a hazard and present vulnerabilities.

Over the years, healthcare organizations and government agencies have developed numerous strategies and guidelines to combat infection. But before organizations can draw up an effective prevention plan, they must consider the existing risks; organizations need a comprehensive and structured approach to assess

hazards and vulnerabilities related to HAIs within a healthcare system.

The Joint Commission for Accreditation of Healthcare Organizations (JCAHO) and Joint Commission International (JCI) standards require accredited organizations to perform an assessment to evaluate their infection risks and set goals and objectives based on the results of the assessment [43].

An Infection Prevention and Control (IPC) Risk Assessment (RA) describes the infection risk which is unique to that particular institution. This Infection Control Risk Assessment (ICRA) will help the institution assess the complexity of the identified risk and define actions that can possibly reduce the effects [44]. In a healthcare organization, infection risks can originate from a variety of areas, such as lack of hand hygiene, unsafe injection practices, poor cleaning, disinfection, sterilization of instruments and scopes, and inadequate environmental cleaning. To understand which risks are the most threatening, the current situation needs to be analyzed.

Operationally, the risk scoring will help determine the severity and the prioritization of each hazard and vulnerability identified: a risk can be categorized as high, medium, or low depending on the estimated severity of harm. Risk assessment is an ongoing process as infection risk changes over time and often rapidly. An infection control risk assessment must consider different elements before establishing IPC policies and procedures, goals, and objectives. A comprehensive, hospital-wide risk assessment plan documenting how the healthcare facility is prioritizing patient and healthcare worker safety is essential in any healthcare organization. It is the first step in a systematic process to raise awareness and to create and implement a PCI Plan [44].

The important issues are whether a known or potential risk is likely to occur, its significance should it occur, and whether the organization is adequately prepared to handle it so that the negative effects are eliminated or minimized. The hospital identifies risks for acquiring and transmitting infections through thoughtful examination of what could cause harm to patients, staff, families, and visitors.

Ideally, RA in IPC is best performed by an experienced IPC practitioner, maybe with input from staff in the clinical area concerned. The IPC practitioner may need assistance from clinicians, laboratory staff, or data managers, depending on the location and type of hazard being investigated.

Risk assessment should be performed when:

- a new IPC service is established, in particular standard precautions, transmission-based precautions, infection surveillance, cleaning, laundry and waste management, reprocessing of reusable instruments, and renovation projects
- a new piece of clinical equipment or an instrument is procured
- a new procedure or diagnostic test is implemented
- a problem in IPC practice or policy, or a related issue is identified
- at least annually to re-evaluate the IPC program priorities

Conducting a risk assessment is a crucial task for healthcare organizations. The point of the process is not to identify and compile risks, but to serve as the basis for developing actionable goals and measurable objectives for the infection control program. In other words, assessment should form the foundation of the organization's infection prevention plan.

Once the most menacing risks have been identified in a healthcare facility and understood, goals and measurable objectives can be developed to combat these threats.

The Joint Commission's Infection Prevention and Control standards require organizations to use the risk assessment process to set goals for a comprehensive infection control plan. Specifically, Standard IC.01.04.01 states that "based on the identified risks, [the organization] sets goals to minimize the possibility of transmitting infections" [43]. The standard includes the following elements of performance:

- The organization's written infection prevention and control goals include the following:
  - Addressing prioritized risks.
  - Limiting unprotected exposure to pathogens.
  - Limiting the transmission of infections associated with procedures.
  - Limiting the transmission of infections associated with the use of medical equipment, devices, and supplies.
  - Improving compliance with hand hygiene guidelines.
- A goal is a broad statement indicating the change we want to make. It identifies a main issue and it is not measurable. For example, goals may include:
  - Improving hand hygiene.
  - Implementing disaster preparedness kits.
  - Reducing the risk of surgical site infections.
- A measurable objective specifies quantifiable results in a specific length of time. It defines the who, what, when, where, and how of our strategy.
- Successful risk management in IPC needs the following key elements that will help to produce effective projects:
  - An active IPC committee that assists with risk assessment and implementation of IPC measures.
  - Robust policies and procedures that lay the foundation for good institutional IPC practice.
  - Committed leadership supporting IPC.
  - A safety culture.

9.4.2 Risk Management Tools

Risk management tools are applicable in infection risk assessment including both reactive and proactive methods. The first, based on the information of internal reporting, will analyze the causes of adverse events (AEs) already occurred, as epidemics or serious infections, in order to propose some corrective actions. They include the following.

9.4.2.1 Root Cause Analysis

Root cause analysis (RCA) is a process for identifying the basic or causal factor(s) underlying variation in performance that can produce unexpected and undesirable adverse outcomes. A root cause analysis focuses primarily on systems and processes, not individual performance. The objective of an RCA must not be to assign individual blame; rather, through RCA, a team works together to understand a process and the causes or potential causes of variation that can lead to error, identifying process changes that would make such variation less likely to recur.

A root cause is the most fundamental reason (or one of several fundamental reasons) a failure or underperformance has occurred. In contrast with the usual use of the word, "cause" does not carry an assignment of blame or responsibility in the context of RCA. Here, the focus is on a positive, preventative approach to changes in a system and its processes following a sentinel event, a near-miss sentinel event, or a cluster of less serious yet potentially harmful incidents. Although root cause analysis is associated more frequently with the investigation of a single event, the methodology can also be used to determine the cause of multiple occurrences of low-harm events. When analyzing events as a cluster, RCA can result in the identification of common error causes.

Root cause analysis is designed to answer the following three questions: (1) What happened? (2) Why did it happen? (3) What can be done to prevent it from happening again? [45].

9.4.2.2 Significant Event Audit

A significant event audit (SEA) is a process in which individual episodes, whether beneficial or deleterious, are analyzed in a systematic and detailed way to ascertain what can be learnt about the overall quality of care and to indicate any changes that might lead to future improvements. Put simply, an SEA is a *qualitative* method of clinical audit. In this respect, it differs from traditional audits that tend to deal with larger scale, *quantifiable* patient data sets and involve criteria and standards which can be measured and com-

pared against. However, SEA should still involve a systematic attempt to investigate, review, and learn from a single event that is deemed to be significant by the healthcare team.

The seconds are performed before the occurrence of AEs and aim to reduce their frequency and/or severity. The seconds should be applied above all in risky environments such as in the ICU. The following subsections provide further detail.

9.4.2.3 Process Analysis

A process is defined as a sequence of successive steps in the service of a goal. Each step is a producer of a specific contribution that needs to be identified in terms of issues, content, and quality-security. The analysis can involve either an existing, high-stakes practice that generates actual or potential dysfunctions or a new practice to be verified before it is implemented.

The steps of analysis are:

- describing a process from start to finish: its objectives, successive steps, actors, etc.
- identifying and analyzing the critical points
- proposing improvements to management for the organization, especially in terms of interfaces between services

This analysis is carried out by all the stakeholders involved and can be completed using the method presented in the nest subsection [46].

9.4.2.4 Failure Modes and Effects Analysis

Failure Modes and Effects Analysis (FMEA) is a systematic, proactive method for evaluating a process to identify where and how it might fail and to assess the relative impact of different failures in order to recognize the parts of the process that need change. FMEA includes the following steps: failure modes (i.e., What could go wrong?), failure causes (i.e., Why would the failure happen?), failure effects (i.e., What would be the consequences of each failure?). Teams use FMEA to evaluate processes for possible failures and to prevent such failures by correcting the processes proactively instead of reacting to adverse events after failures have occurred. This emphasis on prevention may reduce risk of harm to both patients and staff. FMEA is particularly useful in evaluating a new process before its implementation and in assessing the impact of a proposed change to an existing process.

9.4.3 The Best Practices Approach

The United Nations Population Fund's (UNFPA) "Glossary of Monitoring and Evaluation Terms" defines "best practices" as planning or operational practices that have been proven successful in particular circumstances and which are "used to demonstrate what works and what does not and to accumulate and apply knowledge about how and why they work in different situations and contexts."

UNESCO describes best practices as having four common characteristics: being innovative; making a difference; having a sustainable effect; having the potential to be replicated and to serve as a model for generating initiatives elsewhere.

Even if there is not a universally accepted definition, a best practice is a practice that, upon rigorous evaluation, has demonstrated success, has had an impact, and can be replicated. Some best practices in the ICP field are presented in the following subsections.

9.4.3.1 Hand Hygiene

Hand hygiene has long been recognized as the single most effective way to prevent the spread of infections.

The most common cause of HAIs is transient flora acquired and spread by direct contact with patients or with environmental surfaces. If transferred to susceptible sites such as invasive devices (e.g., central venous and urinary catheters) or wounds, these organisms can cause life-threatening infections.

Several studies have demonstrated the effect of hand cleansing on HAIs rates and on the reduction in cross-transmission of antimicrobial-resistant pathogens.

Ease of access to hand washing facilities (e.g., soap and water) and alcohol-based hand rubs can influence the transmission of HAIs.

In 2009, the World Health Organization produced guidelines on hand hygiene in healthcare in which are outlined the "five moments" to perform hand hygiene:

- before touching a patient
- before a clean or aseptic procedure
- after risk of body fluid exposure
- after touching a patient
- after touching a patient's surroundings

Hand hygiene must also be performed before putting on gloves and after their removal.

Evidence suggests that compliance with proper hand hygiene after contact with a patient's surroundings is generally very poor in hospitals, as healthcare workers underestimate the role of environmental surfaces in the transmission of HAIs.

Effective hand hygiene relies on appropriate technique as much as on selection of the correct product. Inappropriate technique may only partially remove or kill microorganisms on hands, despite the superficial appearance of having complied with hand hygiene requirements.

To wash hands correctly, both hands and wrists need to be fully exposed to the product and therefore should be free from jewellery and long-sleeved clothing—in other words, they should be bare below the elbow. Each healthcare facility should develop policies regarding jewellery, artificial fingernails, or nail polish worn by healthcare workers.

Alcohol-based hand rubs are recommended because of their ease of use and availability at the point of care. They are suitable for use except when hands are visibly soiled or potentially contaminated with body fluids, or when caring for patients with vomiting or diarrheal illness. Soap and water should be used in these instances, as well as after contact with patients with *C. difficile* infection or their environment, as alcohol hand rubs are not effective in reducing spore contamination.

When using alcohol gel, hands should be free of dirt and organic material and the solution must come into contact with all the surfaces of the hand; hands should be rubbed vigorously until the solution has evaporated. When washing hands with a liquid soap, the solution should come into contact with all the surfaces of the hands and hands should be rubbed together for a minimum of 10–15 s. Particular attention should be paid to the tips of the fingers, the thumbs, and the areas between the fingers. Hands should be thoroughly rinsed and then dried with a good-quality paper towel [30].

Each year, the "WHO SAVE LIVES: Clean Your Hands" campaign aims to progress the goal of maintaining a global profile on the importance of hand hygiene in healthcare and to bring people together in support of hand hygiene improvement around the world.

9.4.3.2 Antimicrobial Stewardship

Antibiotics, like all medication, may have side effects, including adverse drug reactions and *Clostridioides difficile* infection (CDI). Nevertheless, the misuse of antibiotics has also contributed to the growing problem of antibiotic resistance. Unlike other medications, the potential for the spread of resistant organisms means that the misuse of antibiotics can adversely influence the health of patients who are not even exposed to them.

The relationship between the unrestrained use of antimicrobials in all human health settings as well as agriculture and animal husbandry and the emergence of bacterial resistance is well documented [47].

Infection prevention and control practices are recognized as a key part of an effective response to antimicrobial resistance, as they reduce the need for antimicrobials and the opportunity for organisms to develop resistance. Vaccination can also reduce antimicrobial resistance by preventing infectious diseases, even primary viral infections, often inappropriately treated with antibiotics [2].

Programs dedicated to improving antibiotic use, commonly referred to as "Antibiotic Stewardship Programs" (ASP), can both optimize the treatment of infections and reduce adverse events associated with antibiotic use, thus improving not only the quality of patient care but also patient safety by increasing the fre-

quency of correct prescriptions for both therapy and prophylaxis.

Successful antimicrobial stewardship programs have been associated with reduced facility resistance rates as well as reduced morbidity, mortality, and costs.

Antibiotic stewardship consists of the implementation of policies that support optimal antibiotic use through interventions which are tailored and prioritized depending on the needs of the hospital, the organizational context, and factors such as size of the facility, staffing, and resources.

A systemic integration of antimicrobial, infection prevention, and diagnostic stewardship (AID) has been proposed in order to reduce the need for antimicrobials and the opportunity for organisms to develop resistance [48]. It is necessary for cross-disciplinary borders and approach infection management in an integrated, multidisciplinary manner. Microbiology laboratories and clinical microbiologists can provide significant contributions to ASPs, including the dissemination of antimicrobial susceptibility reports and enhanced culture by means of fast microbiology [49] and diagnostic stewardship [50]. Participating in ASPs is mainly seen as a task for clinical microbiologists and/or infectious disease specialists, together with (hospital) pharmacists. However, such an endeavor deeply involves bedside doctors and nurses, boards of directors, and diagnostic laboratories since patients commonly transition between different healthcare settings. Antimicrobial stewardship programs require multidisciplinary efforts which depend also on the support of the hospital's administration, the allocation of adequate resources, and the cooperation and engagement of prescribers.

Only a comprehensive healthcare network using an integrated approach may contain the spread of antimicrobial resistance. From this perspective, infection management is thus a responsibility for all stakeholders involved in such a network.

It is vital that infection control and prevention measures are integrated into a unified AID program to improve overall infection management. Without the proper infection prevention measures, other interventions such as ASPs and Diagnostic Stewardship Programs (DSP) will not achieve the optimal effect.

Stewardship interventions can be listed in three categories: broad, pharmacy-driven, and infection and syndrome specific. Broad interventions include:

- Antibiotic timeouts accompanied by a reassessment of the continuing need for and choice of antibiotics when more information is available.
- Prior authorization, restricting the use of certain antibiotics bound to preventative evaluation performed by an antibiotic expert.
- Prospective auditing and feedback, with reviews of antibiotic therapy by an expert in antibiotic use not involved in the treatment (e.g., a day-2 bundle with face-to-face case audits performed by the antimicrobial stewardship team) [51].

Pharmacy-driven interventions include:

- Automatic changes from intravenous to oral antibiotic therapy in appropriate situations.
- Dose adjustments in cases of organ dysfunction (e.g., renal adjustment).
- Dose optimization including dose adjustments based on therapeutic drug monitoring.
- Automatic alerts in situations where therapy might be unnecessarily duplicative.
- Time-sensitive automatic stop orders for specified antibiotic prescriptions.
- Detection and prevention of antibiotic-related drug interactions.

Infection and syndrome-specific interventions are intended to improve prescribing for specific syndromes and situations such as community-acquired pneumonia and urinary tract infections, skin and soft tissue infections, empiric coverage of methicillin-resistant *Staphylococcus aureus* (MRSA) infections, *Clostridioides difficile* infections, and treatment of culture proven invasive infections; however, prompt and effective treatment for severe infection or sepsis should be provided in any case [52].

Antimicrobial stewardship programs need to be monitored both at the process level (i.e., Are policies being followed as expected?) and at the outcome level (i.e., Have antibiotic use and patient outcomes improved?) [2, 52].

9.4.3.3 Care Bundles

"Care bundling" is an approach developed by the United States Institute of Healthcare Improvement [53] to help healthcare workers consistently deliver the safest possible care for patients undergoing treatments known to increase patients' risk of healthcare-associated infections. A bundle is a set of evidence-based practices (generally three to five) that improve patient outcomes when performed collectively and reliably.

The elements of a bundle are well-established practices, combined into a structured protocol that is agreed upon and is the responsibility of the whole clinical team. Characteristics of a bundle include the following:

- All elements are necessary and make up a cohesive unit of steps that must be completed in their entirety to succeed; while getting some of them right may be an improvement, it is not as good as getting them all right. The more reliably all the bundle elements are delivered, the better the outcomes [54].
- Each element is based on randomized and controlled trial evidence.
- The bundle involves an all-or-nothing measure which makes implementation clear-cut.

Existing care bundles can be used as tools and developed further by each facility to meet its needs.

Two examples of bundles are described below.

CAUTI Maintenance Bundle

One example of a bundle procedure for the maintenance of urinary catheters includes the following steps:

- Perform a daily review of the need for the urinary catheter.
- Check the catheter has been continuously connected to the drainage system.
- Ensure patients are aware of their role in preventing urinary tract infection, or if the patient is unable to be made aware, perform routine daily meatal hygiene.
- Empty urinary drainage bags frequently enough to maintain urine flow and prevent reflux, using a separate urine collection container for each patient and avoiding contact between drainage bags and the container.
- Perform hand hygiene and put on gloves and apron before each catheter care procedure; on procedure completion, remove gloves and apron and perform hand hygiene again.

Ventilator Bundle

Ventilated patients are at high risk for several serious complications: ventilator-associated pneumonia (VAP), venous thromboembolism (VTE), and stress-induced gastrointestinal bleeding. Five elements of care have been identified for the prevention of these events in ventilated patients and are supported by solid level-one trials:

- elevation of the head of the bed (HOB) to between 30° and 45°
- daily sedative interruption and daily assessment of readiness to extubate
- peptic ulcer disease (PUD) prophylaxis
- deep venous thrombosis (DVT) prophylaxis (unless contraindicated)
- daily oral care with chlorhexidine [55]

9.5 Engaging Patients and Families in Infection Prevention

Engaging patients and families in improving healthcare safety means creating effective partnerships between those who provide care and those who receive it—at every level, including individual clinical encounters, safety committees, executive suites, boardrooms, research teams, and national policy-setting bodies. An effective partnership can generate benefits, both in the form of improved health and outcomes for patients and in safer and more pro-

ductive work environments for healthcare professionals [56].

In healthcare facilities, patients and visitors should be informed about what they can do to prevent the spread of infection and keep themselves infection-free.

Healthcare workers should, where possible:

- explain the processes of infection prevention and control to patients and their caregivers
- engage patients and their caregivers in the decision-making process regarding their care and how it is delivered
- be sure that patients and their caregivers are aware that they can ask questions to healthcare professionals

Written material such as brochures and posters can be used to reinforce verbal discussions with patients as part of their care.

Engagement in hand hygiene can be encouraged by sharing hand hygiene videos with patients and families, asking them to demonstrate proper technique, providing family members and visitors access to hand washing stations and hand hygiene supplies, and asking patients to speak up if they observe staff not following safe practices.

With regard to personal protective equipment (PPE), patients and family members can be provided information at admission about why PPE is being used along with a demonstration of how to don and doff it. It is useful to explain what the hospital is doing to prevent the spread of infections, answering questions with clear and straightforward explanations.

Engagement in antibiotic stewardship involves educating patients on the risks related to the inappropriate use of antibiotics and on what the hospital is doing to monitor the use of antibiotics and to implement good stewardship practices. Patient advocates should be part of the antibiotic stewardship team and data on efforts to reduce inappropriate antibiotic use should be shared, soliciting patient feedback on how best to be included in the efforts [57].

9.6 Identification and Rapid Management of Sepsis: A Test Bed for the Integration of Risk Management and IPC

9.6.1 Sepsis and Septic Shock Today

Sepsis was recently defined as a life-threatening organ dysfunction caused by dysregulated host response to infection [58]. If not recognized early and managed promptly, it can lead to septic shock, multiple organ failure, and death. Any type of infectious pathogen can potentially cause sepsis. Sepsis and septic shock are time-critical, evolving syndromes. The guidelines of the 2017 Surviving Sepsis Campaign [59] identify the crucial components of treatment: resuscitation with fluids, administration of antibiotics, administration of vasopressors, and surgical control of the infectious source.

In the case of suspicion of sepsis and septic shock, it is necessary to act immediately by carrying out the actions of the "sepsis six" [60] bundle complemented by the surgical source control of infection.

For patients with suspected sepsis, the goal is to start antibiotic therapy immediately but with the commitment of all operators to reduce the therapy's duration while maintaining all safety margins and the greatest possible benefits. In 2018, the American society of Infectious Diseases took a critical position with respect to the 2017 Surviving Sepsis Campaign guidelines because they appeared to be excessively inclined to propose standardized indications on the administration of antibiotic therapy, including the clinical management of patients in whom the diagnosis of infection is uncertain. Patients with uncertain diagnosis of infection need to be placed on a clinical path that allows the acquisition of more information by means of appropriate diagnostics and the consequent re-evaluation of their level of risk, as they would not benefit from a standardized and prolonged antibiotic therapy. The benefits of treating patients who are infected need to be weighed against the dangers of treating

patients who are not but at first appear to be. Antimicrobial resistance is a major factor in determining clinical unresponsiveness to treatment and a rapid evolution to sepsis and septic shock. Sepsis patients with resistant pathogens have been found to have a higher risk of hospital mortality.

Septic shock is defined as a sub-type of severe sepsis with lactate greater than or equal to 4 mmol/L or hypotension (i.e., mean arterial pressure (MAP) <65 mm Hg and systolic blood pressure <90 mm Hg) not responsive to fluid bolus [61].

Sepsis is a severe complication of an infection. Anyone affected by an infection can progress to sepsis conditions but some vulnerable populations are at a higher risk, including elderly people, pregnant women, neonates, hospitalized patients, and people with HIV/AIDS, liver cirrhosis, cancer, kidney disease, autoimmune diseases, or no spleen [62].

By this new definition, sepsis is a medical emergency. However, as an evolving, syndromic condition with multiple causative organisms, sepsis can present in patients various signs and symptoms at different times. Warning signs and symptoms include fever or low temperature and shivering, altered mental status, difficulty breathing or rapid breathing, increased heart rate, weak pulse or low blood pressure, low urine output, cyanotic or mottled skin, cold extremities, and extreme body pain or discomfort.

Suspecting sepsis is a first major step toward early recognition and diagnosis [63–65].

There are two main steps to prevent sepsis:

1. prevention of microbial transmission and infection
2. prevention of the development of an infection into sepsis conditions

In both community and healthcare facilities, the prevention of the development of sepsis requires appropriate antibiotic treatment of infections, including reassessment for optimization, seeking medical care promptly, and early detection of sepsis signs and symptoms. Scientific evidence has clearly demonstrated the effectiveness of infection prevention. For instance, improved hand hygiene practice in healthcare can reduce infection by as much as 50% [66].

Identifying and not underestimating signs and symptoms along with detecting biomarkers such as procalcitonin are crucial elements for the early diagnosis of sepsis and the timely establishment of appropriate clinical management. After early recognition, diagnostics that help identify the causal pathogen of infection leading to sepsis are also important to guide targeted antimicrobial treatment. Antimicrobial resistance (AMR) can jeopardize clinical management of sepsis because empirical antibiotic treatment is often required. Therefore, it is important to understand the epidemiology of AMR in the local setting. Once the source of infection is determined, source control such as drainage of an abscess is also critical. Early fluid resuscitation to improve volume status is important in the initial phase of sepsis management. In addition, vasopressors may be required to improve and maintain tissue perfusion. The appropriate management of sepsis over time should be guided by repeated exams and diagnostics, including vital signs monitoring.

9.6.2 Sepsis as an Adverse Event: Failures in Identification and Management

In a recent paper, Rhee et al. [67] reported the findings of a retrospective review of hospital deaths and discharges to hospice in three large academic medical centers and three affiliated community hospitals.

Detailed medical record reviews were performed on 568 in-hospital deaths and discharges to hospice to determine if sepsis was present during the hospitalization and if it was a cause of death. For patients who died with or due to sepsis, investigators identified potential signs of suboptimal sepsis care, including delays in initiating antibiotic therapy or source control, and inadequate fluid resuscitation, and made an overall assessment of the preventability of sepsis-associated death. 264 of the 300 deaths from sepsis (88.0%; 95%CI, 83.8–91.5%) were con-

sidered unpreventable (4–6 rating on the Likert scale) and only 36 deaths (12.0%; 95%CI, 8.6–16.2%) were considered potentially preventable, of which 11 (3.7%) were definitely or moderately likely preventable and 25 (8.3%) were possibly preventable. There were no identifiable suboptimal aspects of care in 232 sepsis-associated deaths (77.3%). Of the 68 cases with suboptimal care (22.7%), the most common problems were:

1. delays in antibiotics, in 33 cases (48.5%)
2. delays in source control, in 19 cases (27.9%)
3. inappropriate empirical antibiotic therapy, in 16 cases (23.5%)

Of these 68 cases, 32 deaths (47.1%) were judged to be definitely, moderately likely, or possibly preventable. Generally, the non-preventable, sepsis-associated deaths occurred in patients with major underlying comorbidities, severe, acute, concurrent illnesses, and/or florid sepsis that progressed despite optimal care. A total of 42 major errors were identified in the 36 sepsis-associated deaths that were potentially preventable. Most of the errors were related to:

1. delays in recognition and treatment of sepsis ($n = 16$)
2. inappropriate antibiotic therapy administered after recognition of sepsis ($n = 10$)
3. delays in source control ($n = 7$)

Two patients had potentially preventable hospital-acquired infections, while three had procedural complications (i.e., bleeding and ischemia) and three had medication-related adverse events (i.e., bleeding from excessive oral anticoagulation) that triggered a cascade of events leading to sepsis and death. One patient was inadequately monitored in a hospital ward after admission and there was delayed recognition of an unstable arrhythmia. Of the 36 potentially preventable deaths, only 1 patient met criteria for hospice on admission (i.e., due to end-stage liver disease). This patient's death was still considered possibly preventable as he did not receive Gram-negative antibiotic coverage for pneumonia caused by *Escherichia coli*. The authors concluded that only a minority of sepsis-associated deaths in this cohort were preventable through better hospital-based care. Conclusions about the prevention of sepsis-associated deaths through better hospital-based care must be contextualized based on the care that is delivered. This study cohort was assembled from patients of three highly regarded academic medical centers and three affiliated community hospitals. The rate of suboptimal sepsis care reported in this cohort—just under 23%—is substantially lower than in other studies. For comparison, in a recent publication from New York State's sepsis improvement efforts, adherence to a 3-h sepsis bundle increased from 53.4% to 64.7% in 183 acute care hospitals during the 27-month study period [68]. An international point prevalence study found only a 19% completion rate of all elements of a 3-h sepsis bundle [69]. The lower rate of suboptimal care reported by Rhee and colleagues suggests that sepsis care in the hospitals included in this study may have been substantially better than that in many other hospitals, with correspondingly less room for improvement and fewer sepsis-associated deaths deemed to be preventable through better hospital care; in hospitals with more deficiencies in sepsis care, more deaths from sepsis may be preventable. Despite the challenge of identifying which sepsis-associated deaths may be potentially preventable, Rhee's study does reflect the reality that some sepsis-associated deaths are not preventable with the tools currently available for the recognition and management of sepsis. This finding should serve as a call to action to advance the sepsis research agenda [70]. Early recognition and prompt management of sepsis have been associated in numerous studies with improved patient outcomes, and current clinical practice guidelines emphasize this concept [59].

9.7 Conclusions

Successful approaches for preventing and reducing HAIs involve implementing a risk management framework to manage both human and

systemic factors associated with the transmission of infectious agents.

Infection prevention in healthcare facilities mainly relies on properly functioning infection prevention and control programs and teams, effective hygiene practices and precautions, including hand hygiene, along with clean, well-functioning environments and equipment.

The implementation of best practices and the replication of improvement actions deserve a context-focused approach that targets the specific risks and hazards appearing in given scenarios. In the future, infection prevention needs to become adaptive by embodying an array of techniques and methods to assess risks and design targeted solutions that rely on the fostering of multidisciplinary healthcare teams.

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