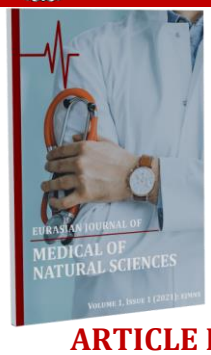
EURASIAN JOURNAL OF MEDICAL AND NATURAL SCIENCES
Innovative Academy Research Support Center
IF = 7.921 www.in-academy.uz



NOSOCOMIAL INFECTIONS: CHALLENGES, PREVENTION STRATEGIES, AND ADVANCES IN CLINICAL MANAGEMENT

Bazarova Gulnora Rustamovna
Associate Professor at the "Alfraganus "university's medical faculty
Email: gulnorabazarova599@gmail.com
Orcid Id:0009-0006-7621-2642
https://doi.org/10.5281/zenodo.14906152

ARTICLE INFO

Received: 15th February 2025
Accepted: 20th February 2025
Online: 21st February 2025

KEYWORDS

Nosocomial Infections; Healthcare-Associated Infections (HAI); CLABSI; CAUTI; SSI; VAP; CDI; Infection Prevention; Hand Hygiene; Antimicrobial Stewardship.

ABSTRACT

This article offers a comprehensive review of the key aspects of nosocomial infections. It discusses the significance of healthcare-acquired infections, examines the various types, and outlines effective prevention and management strategies. The activity also explores methods for evaluating and treating nosocomial infections, while emphasizing the crucial role of the healthcare team in improving patient care and outcomes.

Objectives:

- Identify the underlying causes of nosocomial infections.
- Describe effective approaches for evaluating nosocomial infections.
- Explain the available treatment options for managing these infections.
- Outline interprofessional strategies to enhance care coordination and communication, ultimately reducing nosocomial infections and improving patient outcomes.

Introduction

Nosocomial infections, also known as healthcare-associated infections (HAIs), are infections acquired by patients during the course of receiving medical care, which were not present at the time of admission. These infections can occur in various healthcare settings—including hospitals, long-term care facilities, and outpatient clinics—and may even manifest after discharge. HAIs also encompass occupational infections affecting healthcare staff.

Infections develop when pathogens spread to a susceptible patient. In modern healthcare, factors such as invasive procedures, surgeries, indwelling medical devices, and prosthetic implants are closely associated with these infections. The causes of HAIs vary based on the source or type of infection and can be due to bacterial, viral, or fungal pathogens.

HAIs are the most common adverse events impacting patient safety, significantly contributing to morbidity, mortality, and financial burdens on patients, families, and healthcare systems. The emergence of multi-drug resistant organisms further complicates this issue. In the United States, HAIs affect roughly 3.2% of hospitalized patients, while in the European Union/European Economic Area, the rate is around 6.5%, with the global prevalence likely even higher. Although the full worldwide burden remains uncertain due to

limited surveillance systems, substantial efforts are underway through infection prevention and control programs to develop effective monitoring and control strategies.

Etiology

Types of Healthcare-Associated Infections (HAIs)

Healthcare-associated infections (HAIs) arise from a range of pathogens that can be traced back to various sources, and they manifest in multiple forms. The Centers for Disease Control and Prevention categorizes HAIs into several major types, including central line-associated bloodstream infections (CLABSI), catheter-associated urinary tract infections (CAUTI), surgical site infections (SSI), and ventilator-associated pneumonia (VAP). Other categories include non-ventilator-associated hospital-acquired pneumonia (NV-HAP), gastrointestinal infections (such as those caused by Clostridioides difficile), primary bloodstream infections not linked to central catheter use, and urinary tract infections unrelated to catheterization. Additionally, HAIs can be grouped by the affected organ systems, covering infections of the ear, eye, nose, and throat; lower respiratory tract infections (such as bronchitis, tracheobronchitis, bronchiolitis, tracheitis, lung abscesses, or empyema without pneumonia); skin and soft tissue infections; cardiovascular infections; bone and joint infections; central nervous system infections; and reproductive tract infections.

A 2015 point-prevalence survey in the United States found that pneumonia is the most common HAI in acute hospital settings, followed by gastrointestinal infections, surgical site infections, other system-specific infections, bloodstream infections, and urinary tract infections. This survey also noted that non-ventilator-associated hospital-acquired pneumonia (NV-HAP) is the most prevalent type in these settings—a finding consistent with European studies. These trends differ slightly from a 2011 survey, where pneumonia and surgical site infections each accounted for 21.8% of HAIs, followed by gastrointestinal infections (17.1%), urinary tract infections (12.9%), and bloodstream infections (9.9%).

Pathogens Responsible for HAIs

Nosocomial infections can be caused by bacteria, viruses, and fungi, each exhibiting distinct traits that make them more likely to infect susceptible hosts. The prevalence of these pathogens varies by healthcare facility, setting, and patient demographics, with bacteria being the most common, followed by fungi and viruses.

Bacteria

Bacterial pathogens may come from external sources or be part of the patient's normal flora, with opportunistic infections often occurring when the immune system is compromised. Common Gram-positive bacteria include coagulase-negative Staphylococci, Staphylococcus aureus, various Streptococcus species, and Enterococcus species such as faecalis and faecium. In U.S. hospitals, Clostridioides difficile is the most frequently reported HAI pathogen, accounting for 15% of infections with an identified pathogen. Among Gram-negative bacteria, common culprits include members of the Enterobacteriaceae family—such as Klebsiella pneumoniae, Klebsiella oxytoca, Escherichia coli, Proteus mirabilis, and Enterobacter species—as well as Pseudomonas aeruginosa, Acinetobacter baumannii, and Burkholderia cepacia. Acinetobacter baumannii, in particular, is associated with high mortality in intensive care settings due to its multidrug-resistant properties.

Multidrug-resistant bacteria are a significant concern in HAIs and contribute to high mortality rates. Studies indicate that around 20% of reported pathogens in HAIs exhibit multidrug resistance. Notable multidrug-resistant organisms include methicillin-resistant Staphylococcus aureus (MRSA), vancomycin-intermediate and vancomycin-resistant Staphylococcus aureus (VISA/VRSA), Enterobacteriaceae producing extended-spectrum beta-lactamases (ESBLs), vancomycin-resistant Enterococcus (VRE), carbapenem-resistant Enterobacteriaceae and Acinetobacter species, and multidrug-resistant Pseudomonas aeruginosa.

Fungi

Fungal infections are typically opportunistic, affecting immunocompromised patients or those with indwelling devices such as central lines or urinary catheters. Candida species—such as C. albicans, C. parapsilosis, and C. glabrata—are the most commonly encountered fungal pathogens in HAIs, with Candida auris emerging as a particularly problematic, multidrug-resistant organism characterized by high morbidity and mortality due to diagnostic challenges and treatment failures. Overall, Candida species rank as the fourth most common pathogens in HAIs. Additionally, Aspergillus fumigatus infections may occur from airborne environmental contamination, particularly in healthcare settings undergoing construction, although infected patients can also serve as a source.

Viruses

Viral pathogens account for only 1–5% of HAIs. Healthcare-associated transmission of viruses such as hepatitis B, hepatitis C, and HIV is often linked to unsafe needle practices, with an estimated 5.4% of global HIV infections being healthcare-associated—especially in developing regions. Other viral agents reported in HAIs include rhinovirus, cytomegalovirus, herpes simplex virus, rotavirus, and influenza.

Epidemiology

Nosocomial infections impact a significant number of patients worldwide, increasing mortality and imposing a substantial financial burden on healthcare systems. Although the true global extent of healthcare-associated infections (HAIs) remains uncertain due to limited data and surveillance, studies from Europe and the United States offer consistent insights, making these regions key sources of epidemiologic information.

In European hospitals, the prevalence of at least one HAI varies by care setting: roughly 4.4% in primary care hospitals, 7.1% in tertiary care hospitals, 19.2% in intensive care units, and 3.7% in long-term care facilities. It is estimated that nearly 8.9 million distinct HAI episodes occur annually in acute care and long-term healthcare facilities within the European Union. Notably, the European Prevalence of Infection in Intensive Care study reported a 20.6% rate of ICU-acquired infections.

In the United States, a 2015 survey found that 3.2% of hospitalized patients developed an HAI—a decrease from 4% reported in a 2011 study. Among HAIs in U.S. healthcare facilities, 36.4% occurred in critical care areas, 57.5% in ward or nursery settings, and 6.1% in step-down or specialty care units, or in areas with mixed acuity levels.

Earlier research indicated that the highest rates of HAI acquisition occurred among adults and children outside the ICU, followed by ICU patients, high-risk neonate nurseries, and then well-baby nurseries. In 2015, U.S. hospitals were estimated to have recorded 687,200

HAI episodes, affecting approximately 633,300 patients—a significant improvement compared to the 1.7 million episodes estimated in 2002.

In developing countries, the burden of HAIs appears even higher. A pooled analysis revealed an overall HAI prevalence of 15.5%, with ventilator-associated pneumonia (VAP) and neonatal infections in intensive care settings being especially common. Additionally, a systematic review in Southeast Asian countries reported an overall HAI prevalence of 9.1%.

Pathophysiology

Routes of Transmission

Pathogens responsible for healthcare-associated infections (HAIs) can spread via several transmission routes. The most common is contact transmission, where organisms are passed directly or indirectly from one surface or person to another. This route is frequently responsible for the spread of multidrug-resistant bacteria (e.g., MRSA, ESBL-producing Gram-negative organisms, VRE), Clostridioides difficile, and rotavirus. In contrast, droplet transmission occurs when large respiratory droplets (greater than 5 microns) travel short distances—typically under three feet—carrying pathogens such as influenza, Bordetella pertussis, and Neisseria meningitidis. Airborne transmission involves smaller droplets (less than 5 microns) that can travel over longer distances, facilitating the spread of diseases like chickenpox, tuberculosis, measles, and SARS-CoV-2.

Central Line-Associated Bloodstream Infection (CLABSI)

CLABSI develops in patients with central venous catheters and is among the most preventable HAIs. In many healthcare settings, a significant number of both ICU and non-ICU patients have central venous catheters. CLABSI typically results from the proliferation of skin bacteria along the external surface of the catheter into the bloodstream. Other causes include contamination during insertion or manipulation, or via hematogenous spread. Bacterial and fungal pathogens implicated in CLABSI often form biofilms, which enhance their adherence and proliferation on these devices. Common causative organisms include Staphylococcus aureus, Candida species, coagulase-negative Staphylococci, Enterococcus species, Streptococcus species, Escherichia coli, and Bacteroides species. Notably, antimicrobial resistance among these pathogens is a serious concern.

Risk factors for CLABSI can be divided into host factors—such as immunosuppression, chronic illness, neutropenia, malnutrition, parenteral nutrition, extremes of age, and bone marrow transplantation—and catheter-related factors, including prolonged hospitalization before catheterization, extended duration of catheter use, use of multi-lumen catheters, the catheter material, multiple catheter placements, urgent insertions, and breaches in aseptic technique. There remains some debate regarding whether femoral catheters pose a higher risk compared to those placed in the subclavian or jugular veins.

Catheter-Associated Urinary Tract Infection (CAUTI)

CAUTI occurs in patients with indwelling urinary catheters, which are commonly used for various medical reasons. A considerable proportion of hospitalized patients have urinary catheters, making CAUTI a frequent complication. These infections can be classified as either extraluminal, where bacteria travel along the catheter's outer surface from the urethral opening to the bladder, or intraluminal, which usually results from urinary stasis due to blocked drainage or ascending infection from within the catheter. Biofilm formation by

bacteria and fungi plays a crucial role in facilitating these infections. Typically, the pathogens originate from the patient's own fecal or skin flora, with Escherichia coli being the most common, followed by organisms such as Klebsiella pneumoniae/oxytoca, Enterococcus species, Pseudomonas aeruginosa, and Candida species. CAUTI can lead to complications like upper urinary tract infections, sepsis, and bacteremia. The duration of catheterization is the most critical risk factor, along with nonadherence to aseptic protocols during insertion. Additional patient-related risk factors include female sex, paraplegia, cerebrovascular disease, advanced age, diabetes, a history of urinary tract infections, and recent antibiotic use.

Skin and Soft Tissue Infection (SSI)

SSIs occur in a subset of patients following surgery, typically manifesting within 30 days of the procedure or within 90 days if an implant is involved. These infections are categorized based on their depth and location: superficial SSIs involve only the skin and subcutaneous tissue, deep SSIs extend into muscle or fascia, and organ/space SSIs affect the anatomical region surrounding the surgical site. The patient's normal flora—especially from the skin, gastrointestinal tract, and female genital tract—can contaminate the surgical site, depending on the type of surgery. Procedure-related risk factors include the length of the surgery, wound classification (with dirty, contaminated, or clean-contaminated wounds posing higher risks than clean wounds), intraoperative hypothermia, hypovolemia, hypoxemia, surgical urgency, multiple interventions, the need for blood transfusions, and the type of prosthetic material used. Postoperative factors, such as the presence of wound drains, inadequate wound hygiene, and extended hospital stays, further elevate the risk. Patient-related factors, including immunosuppression, smoking, obesity, hyperglycemia, malnutrition, joint disease, and older age, also contribute. Common pathogens associated with SSI include Escherichia coli, Staphylococcus aureus, Klebsiella species, Enterobacter species, Enterococcus species, Streptococcus species, and coagulase-negative Staphylococci. Infections originating from external sources, such as surgical instruments or the environment, occur less frequently and are often seen in clusters.

Pneumonia

Hospital-acquired pneumonia (HAP) is defined as pneumonia developing after 48 hours of hospital admission, while ventilator-associated pneumonia (VAP) occurs following 48 hours of endotracheal intubation. Approximately 5–15% of patients on mechanical ventilation develop VAP. HAP can result from aspiration, inhalation of contaminated aerosols, bacterial translocation, or hematogenous spread. The pathogens commonly associated with HAP and VAP include Staphylococcus aureus, Pseudomonas aeruginosa, Candida species, Klebsiella species, Streptococcus species, and Enterobacter species, with multidrug-resistant organisms being particularly common in VAP cases. Host susceptibility depends on both local factors—such as preexisting lung conditions—and systemic factors like immunosuppression, neutropenia, advanced age, dysphagia, and recent abdominal or thoracic surgery. Additional risk factors for VAP include mechanical ventilation, sedation, supine positioning, poor oral hygiene, physical deconditioning, and reintubation. Factors predisposing to multidrug-resistant HAP or VAP include recent intravenous antibiotic use, the need for ventilatory support, septic shock, acute respiratory distress syndrome preceding pneumonia onset, prolonged hospitalization, and the need for renal replacement therapy.

Clostridioides difficile Infection (CDI)

Clostridioides difficile is the most frequently encountered pathogen in HAIs and is the primary cause of antibiotic-associated diarrhea and colitis. Colonization of the intestinal tract occurs mainly via the fecal-oral route, although aerosolization of spores can also contribute. The bacterium produces toxins that damage intestinal epithelial cells, leading to tissue injury and diarrhea. The most significant modifiable risk factors for healthcare-onset CDI include prior antibiotic use and environmental contamination. Other risk factors include older age, hospitalization, multiple comorbidities, the use of gastric acid suppressants, and immunosuppression.

History and Physical

The clinical presentation of healthcare-associated infections (HAIs) varies based on the specific type of infection, the pathogen involved, and the severity of illness.

Central Line-Associated Bloodstream Infection (CLABSI):

Patients with CLABSI typically present with fever and chills due to bacteremia, often occurring in those with a central venous catheter at the time of infection or within 48 hours after its removal. Although purulent discharge or redness at the catheter insertion site and catheter malfunction may be observed, their absence does not rule out CLABSI. In some cases, complications of bloodstream infections—such as endocarditis, suppurative thrombophlebitis, septic arthritis, osteomyelitis, or abscess formation—may be the initial indication of infection.

Catheter-Associated Urinary Tract Infection (CAUTI):

The signs and symptoms of CAUTI are similar to those of other urinary tract infections but occur in patients with indwelling urethral or suprapubic catheters, those undergoing intermittent catheterization, or within 48 hours after catheter removal. Common manifestations include fever, tenderness in the suprapubic area or costovertebral angle, acute hematuria, catheter blockage, dysuria, and a sense of urgency.

Skin and Soft Tissue Infection (SSI):

SSIs display a range of clinical features depending on the infection's location, depth, and the pathogens involved. These infections typically develop within 30 days after surgery—or up to 90 days if prosthetic devices are involved. Superficial infections often present with redness, warmth, pain, and wound dehiscence, sometimes accompanied by purulent drainage. In contrast, deep tissue or organ/space infections may be less obvious and are usually associated with systemic symptoms such as high fever, chills, severe pain, and elevated white blood cell counts. Postoperative drains may also release purulent material in these cases.

Pneumonia:

Hospital-acquired pneumonia (HAP) is characterized by the onset of new fever, cough, purulent sputum, and declining oxygen levels after at least 48 hours of hospitalization. Ventilator-associated pneumonia (VAP) follows a similar pattern but occurs after 48 hours of endotracheal intubation. In sedated, mechanically ventilated patients, signs may include fever, increased oxygen requirements, and the presence of purulent secretions on endotracheal suctioning. On physical exam, coarse breath sounds, rales, and diminished breath sounds in areas of parapneumonic effusion may be noted.

Healthcare Facility Onset Clostridioides difficile Infection (HO-CDI):

HO-CDI should be considered when patients exhibit unexplained symptoms of CDI, typically defined as three or more unformed stools within a 24-hour period, occurring within three days of hospital admission. Diarrhea is the hallmark symptom, but patients may also experience abdominal pain, cramping, distention, fever, nausea, anorexia, and dehydration, especially in the context of recent antibiotic use.

Special Considerations:

It is crucial to recognize that immunocompromised and elderly patients might not exhibit robust immune responses. In these populations, subtle changes such as altered mental status, lethargy, fatigue, or deviations in baseline vital signs (such as tachycardia, hypotension, or changes in respiratory status) should prompt a high index of suspicion for underlying infection.

Evaluation

In addition to clinical findings and physical examination, various laboratory tests and diagnostic procedures are used to confirm healthcare-associated infections (HAIs). Routine blood tests—including complete blood counts, metabolic panels, inflammatory markers, and blood gases—are essential in the evaluation process. The diagnostic approach varies depending on the type of HAI, as outlined below.

Central Line-Associated Bloodstream Infection (CLABSI):

When CLABSI is suspected in the absence of other localized infections, blood cultures should be obtained. Ideally, samples should be drawn from two separate sites—one from the central venous catheter (CVC) and another from a peripheral vein—before initiating antibiotic therapy. Any purulent material at the catheter insertion site should also be cultured.

Catheter-Associated Urinary Tract Infection (CAUTI):

For CAUTI, urine samples are best collected as midstream specimens after catheter removal, if possible, to avoid contamination from biofilms on the catheter walls. Both urinalysis and urine cultures are recommended. Pyuria is common in catheterized patients with bacteriuria. Asymptomatic bacteriuria, defined by a culture growth of 100,000 colony-forming units per milliliter (CFU/mL) of uropathogenic bacteria without UTI symptoms, typically does not require treatment. In patients exhibiting clinical signs of CAUTI not explained by other sources, a urine culture showing more than 1,000 CFU/mL of one or more pathogens supports the diagnosis.

Skin and Soft Tissue Infection (SSI):

The evaluation of SSI is guided by clinical presentation. When SSI is suspected, samples from the infected tissue, drainage, or purulent material should be collected for culture and susceptibility testing. Deep wound samples can be obtained using swabs, though superficial swabs may be contaminated by polymicrobial colonization. Imaging techniques may also be used to detect deep tissue or organ/space infections, particularly to aid in the drainage of abscesses or infected fluid collections.

Hospital-Acquired Pneumonia (HAP)/Ventilator-Associated Pneumonia (VAP):

A clinical diagnosis of pneumonia should be confirmed with radiographic imaging and microbiological testing. A chest X-ray is commonly used and may reveal new infiltrates, while blood tests may indicate leukocytosis or leukopenia. Sputum samples, obtained noninvasively via expectoration or endotracheal aspiration, or through bronchoscopy with bronchoalveolar

lavage or specimen brushing, should be collected for staining, culture, and antibiotic susceptibility testing. In certain cases, specialized culture media may be necessary to grow fastidious organisms, such as Mycobacterium tuberculosis or fungal pathogens.

Clostridioides difficile Infection (CDI):

For suspected CDI, stool tests for C. difficile toxins or toxin genes should be performed using liquid stool from patients with clinically significant diarrhea to avoid false positives from overly sensitive tests. In patients with ileus and suspected CDI, a rectal swab may be used. An algorithmic approach is recommended, starting with an enzyme immunoassay for toxins A and B along with glutamate dehydrogenase antigen testing; indeterminate results should be confirmed with nucleic acid amplification testing (NAAT). Although colonoscopy is not typically used solely for diagnosing CDI, the presence of pseudomembranous colitis is highly suggestive of the infection. Radiographic imaging may be warranted in severe cases, especially when toxic megacolon or perforation is suspected.

Treatment / Management

Central Line-Associated Bloodstream Infection (CLABSI):

For CLABSI, removal of the central venous catheter (CVC) should be considered in certain cases, particularly when infections are caused by pathogens like Candida, S. aureus, or Pseudomonas. In such cases, the infected catheter should be removed and replaced at a different site after subsequent blood cultures confirm clearance. Antimicrobial therapy and treatment duration are tailored based on the specific pathogen and the infection's severity. Further investigations for potential metastatic infection should be pursued if bacteremia persists after catheter removal, and a second set of blood cultures is essential to verify eradication. Preventing CLABSI is critical and can be achieved through meticulous hand hygiene, proper skin disinfection with chlorhexidine, and strict adherence to aseptic techniques. Other preventative measures include daily assessment of the necessity for a CVC, reducing the number of catheters, and using catheters with the minimum required lumens.

Catheter-Associated Urinary Tract Infection (CAUTI):

Effective management of CAUTI involves both appropriate catheter care and antimicrobial therapy. Reducing the use and duration of indwelling catheters is paramount, with daily evaluations to determine if continued catheterization is necessary. Whenever possible, intermittent catheterization is preferred over continuous use to lower the risk of infection. In CAUTI cases, the removal of the urinary catheter is recommended after two weeks due to biofilm formation and diminishing responses to antibiotics. Antimicrobial therapy should be guided by urine culture and susceptibility testing, using hospital or community antibiograms to direct initial treatment. The role of antiseptic-coated catheters, collection bags, or antimicrobial irrigation remains controversial due to concerns about promoting antimicrobial resistance.

Skin and Soft Tissue Infection (SSI):

Treatment of SSIs typically involves surgical debridement of necrotic tissue and drainage of any purulent collections, such as abscesses. Empiric broad-spectrum antimicrobial therapy should be initiated, with subsequent narrowing of coverage based on culture results and the clinical scenario, keeping in mind that cultures may not always capture all organisms in polymicrobial infections. Preventative strategies for SSI are categorized into

preoperative, intraoperative, and postoperative measures. Preoperative strategies include reducing modifiable risk factors, administering appropriate antibiotics, and decolonizing specific pathogens when indicated. If hair removal is necessary, clipping is preferred over shaving to avoid microtrauma. Intraoperative measures focus on maintaining normothermia, euvolemia, and proper oxygenation, alongside achieving good glycemic control and re-dosing antibiotics as needed during prolonged surgeries. Postoperative management includes diligent wound care, monitoring of dressings and drains, and, in certain high-risk cases, the use of prophylactic antibiotics.

Pneumonia (HAP/VAP):

Management of hospital-acquired pneumonia (HAP) and ventilator-associated pneumonia (VAP) should be guided by respiratory culture results and radiographic findings, typically with a chest X-ray revealing new infiltrates and abnormal white blood cell counts. Sputum samples obtained through expectoration, endotracheal aspiration, or bronchoscopy should be analyzed for appropriate antimicrobial susceptibility. Empiric therapy for VAP usually includes coverage for Pseudomonas aeruginosa, MRSA, and other gram-negative bacilli, with dual antipseudomonal agents used based on patient risk factors and local antibiograms. For suspected aspiration pneumonia, coverage for oral anaerobes is recommended. Treatment should be de-escalated based on culture results and clinical response, and if symptoms fail to improve within 72 hours or the patient deteriorates, further investigation for complications or alternative sources should be undertaken. Preventative strategies for VAP include minimizing the duration of mechanical ventilation, reducing sedation levels, and promoting early mobilization.

Clostridioides difficile Infection (CDI):

Management of hospital-acquired CDI mirrors that of community-acquired cases. When CDI is associated with antibiotic use, discontinuing the inciting antibiotic is the first step. Treatment options include oral vancomycin, fidaxomicin, and metronidazole, with therapy duration determined by the severity of the illness, the recurrence of infection, and any concurrent antibiotic use. In severe cases, surgical evaluation or fecal microbiota transplantation may be necessary. Preventative measures for HO-CDI focus on early detection, prompt patient isolation, adherence to contact precautions, rigorous hand hygiene, thorough environmental cleaning, and strong antimicrobial stewardship programs.

Prognosis

The outcome of healthcare-associated infections (HAIs) varies based on the type of infection, the severity of the patient's illness, and the specific pathogen involved. Although comprehensive global data are lacking due to limited surveillance, numerous studies provide insights into the burden of HAIs, particularly regarding mortality, extended hospital stays, and financial costs.

Mortality:

While the exact global mortality attributable to HAIs is not clearly defined, some studies indicate a 30-day mortality rate of around 10% in patients with HAIs. Other research suggests that crude mortality rates can range from 12% to 80%, depending on definitions and patient populations. Critically ill patients tend to experience higher excess mortality even after adjusting for admission prognostic factors. For example, one international study found that

ICU mortality was 25% for patients with HAIs compared to 11% for those without, and overall hospital mortality was nearly double—30% versus 15%. In the United States, estimates from 2002 attributed nearly 99,000 deaths to HAIs, with pneumonia, bloodstream infections, urinary tract infections, surgical site infections, and other infections each contributing to the overall mortality.

Length of Hospital Stay:

The additional length of hospital stay due to HAIs depends on both the site of infection and the specific type. Surveillance data from a German hospital indicated that HAIs add an average of 12 extra days of hospitalization across all units, with infections such as CAUTI, SSI, and primary bloodstream infections contributing an extra 3.3, 12.9, and 12.5 days respectively. Patients with multiple HAIs may have their hospital stays extended by up to 25.6 days. In U.S. hospitals, patients with HAIs have been observed to stay an average of 26.3 days compared to 5.7 days for those without HAIs, while studies in developing countries report additional stays ranging from 5 to 23 days.

Associated Costs:

The economic impact of HAIs is significant. In U.S. acute care hospitals alone, the annual cost for the five major types of HAIs is estimated to be nearly $10 billion for adult inpatient populations. The most expensive infections include surgical site infections (accounting for about 33.7% of the costs), followed by ventilator-associated pneumonia (31.7%), central line-associated bloodstream infections (18.9%), Clostridioides difficile infection (15.4%), and catheter-associated urinary tract infections (0.3%). Overall, the Centers for Disease Control and Prevention (CDC) estimates that HAIs cost the U.S. healthcare system between $28 billion and $45 billion annually, while in Europe, the annual HAI-associated costs are approximately €7 billion.

Deterrence and Patient Education

Prevention:

Effective hand hygiene is the cornerstone of infection control and the prevention of healthcare-associated infections (HAIs). Routine hand cleaning effectively removes transient pathogenic microorganisms from healthcare workers, thereby reducing the risk of transmission to patients. It also protects healthcare providers themselves and prevents environmental contamination. The World Health Organization emphasizes five key moments for hand hygiene:

- Before patient contact
- Prior to any clean or aseptic procedure
- After exposure to body fluids
- After patient contact
- After contact with the patient's surroundings

Alcohol-based hand sanitizers are generally preferred over soap and water, except when hands are visibly soiled, following contact with body fluids (e.g., after using the toilet), or when exposure to spore-forming pathogens such as *C. difficile* occurs. Numerous studies have demonstrated that adherence to proper hand hygiene significantly lowers microbial loads and reduces HAI transmission.

Standard precautions are essential to protect healthcare workers. These include using personal protective equipment (PPE) such as gloves, gowns, masks, and eye protection to shield against blood and body fluids. Additionally, transmission-based precautions are critical for preventing airborne, droplet, and contact spread. For airborne pathogens, a fit-tested N95 respirator and placement of the patient in a negative pressure isolation room are recommended. To curb droplet transmission, surgical masks and physical distancing should be employed, and for contact precautions—especially against multidrug-resistant organisms and *C. difficile*—patients should be placed in single rooms while healthcare workers wear gowns and gloves. Aseptic techniques are imperative during invasive procedures and surgical interventions.

Environmental contamination is another significant route for pathogen transmission. Studies have identified hospital water taps, door handles, and work surfaces as frequent reservoirs of microbes. Patient equipment and environmental surfaces must be regularly sanitized, and hospital waste—estimated to have a 20–25% potential to cause HAIs—must be handled and disposed of properly. Rigorous cleaning protocols and monitoring are essential to reduce environmental transmission.

Antimicrobial stewardship plays a crucial role in HAI prevention by ensuring appropriate antibiotic use and monitoring resistance patterns. With an estimated 50% of antibiotic prescriptions being unnecessary, overuse not only increases the risk of side effects and *C. difficile* infection but also exacerbates the problem of antibiotic resistance.

Patient Education:

Educating patients about the risks associated with HAIs is vital. Healthcare providers should evaluate each patient's individual risk factors for infection and work to minimize modifiable risks. For example, patients should be advised on how lifestyle choices—such as quitting smoking or proper skin care before surgery—can lower the risk of surgical site infections. Additionally, careful management of invasive devices and judicious use of antibiotics are critical components of reducing infection risks. Informing patients about when and how antibiotics should be used can help prevent misuse and further reduce the spread of antimicrobial resistance.

Enhancing Healthcare Team Outcomes

Historically, healthcare-associated infections (HAIs) were seen as an unavoidable risk of care. However, systematic reviews from U.S. hospitals suggest that while complete eradication of HAIs may not be feasible, a substantial proportion of these infections—up to 65–70% of central line-associated bloodstream infections (CLABSI) and catheter-associated urinary tract infections (CAUTI), and 55% of ventilator-associated pneumonia (VAP) and surgical site infections (SSI)—can be prevented through effective infection control strategies. With the growing emphasis on infection prevention and control programs, there have been notable improvements in HAI rates and shifts in the types of infections encountered. Eliminating HAIs remains a primary objective for healthcare teams, and global organizations are working to implement robust infection prevention and control measures, especially in developing countries.

Infection prevention and control programs are fundamental quality improvement initiatives that use standardized protocols and targeted interventions to minimize the risk of

infection transmission within healthcare settings. Multidisciplinary infection prevention teams collaborate with healthcare providers and staff to develop, implement, and monitor these protocols. Key interventions include educating healthcare personnel, rigorous hand hygiene, regular cleaning and disinfection of medical equipment, environmental decontamination, appropriate isolation precautions, and continuous surveillance and data analysis. These efforts primarily focus on frontline staff such as nurses, physicians, medical technicians, and environmental services personnel.

Pharmacists contribute by overseeing antimicrobial stewardship programs to curb inappropriate antibiotic use and prevent the emergence of resistant organisms, while laboratory technicians support these efforts by tracking antibiograms and susceptibility patterns.

Research indicates that robust infection prevention and control measures not only reduce the length of hospital stays but also significantly lower healthcare costs. Estimates suggest that hospitals can prevent tens of thousands to hundreds of thousands of HAIs annually, resulting in cost savings ranging from millions to billions of dollars. Recent studies have demonstrated that the cost to eliminate a single HAI is relatively low compared to the substantial financial benefits, making HAI reduction programs highly profitable from an administrative perspective. Reducing HAIs also shortens hospital stays, thereby increasing bed availability and further justifying the investment in these prevention initiatives.

References:

1. Magill SS, O'Leary E, Janelle SJ, Thompson DL, Dumyati G, Nadle J, Wilson LE, Kainer MA, Lynfield R, Greissman S, Ray SM, Beldavs Z, Gross C, Bamberg W, Sievers M, Concannon C, Buhr N, Warnke L, Maloney M, Ocampo V, Brooks J, Oyewumi T, Sharmin S, Richards K, Rainbow J, Samper M, Hancock EB, Leaptrot D, Scalise E, Badrun F, Phelps R, Edwards JR., Emerging Infections Program Hospital Prevalence Survey Team. Changes in Prevalence of Health Care-Associated Infections in U.S. Hospitals. N Engl J Med. 2018 Nov 01;379(18):1732-1744. [PMC free article] [PubMed]

2. Suetens C, Latour K, Kärki T, Ricchizzi E, Kinross P, Moro ML, Jans B, Hopkins S, Hansen S, Lyytikäinen O, Reilly J, Deptula A, Zingg W, Plachouras D, Monnet DL., Healthcare-Associated Infections Prevalence Study Group. Prevalence of healthcare-associated infections, estimated incidence and composite antimicrobial resistance index in acute care hospitals and long-term care facilities: results from two European point prevalence surveys, 2016 to 2017. Euro Surveill. 2018 Nov;23(46) [PMC free article] [PubMed]

3. Allegranzi B, Bagheri Nejad S, Combescure C, Graafmans W, Attar H, Donaldson L, Pittet D. Burden of endemic health-care-associated infection in developing countries: systematic review and meta-analysis. Lancet. 2011 Jan 15;377(9761):228-41. [PubMed]

4. Storr J, Twyman A, Zingg W, Damani N, Kilpatrick C, Reilly J, Price L, Egger M, Grayson ML, Kelley E, Allegranzi B., WHO Guidelines Development Group. Core components for effective infection prevention and control programmes: new WHO evidence-based recommendations. Antimicrob Resist Infect Control. 2017;6:6. [PMC free article] [PubMed]

5. Magill SS, Edwards JR, Bamberg W, Beldavs ZG, Dumyati G, Kainer MA, Lynfield R, Maloney M, McAllister-Hollod L, Nadle J, Ray SM, Thompson DL, Wilson LE, Fridkin SK.,

Emerging Infections Program Healthcare-Associated Infections and Antimicrobial Use Prevalence Survey Team. Multistate point-prevalence survey of health care-associated infections. N Engl J Med. 2014 Mar 27;370(13):1198-208. [PMC free article] [PubMed]

6. Ewan VC, Witham MD, Kiernan M, Simpson AJ. Hospital-acquired pneumonia surveillance-an unmet need. Lancet Respir Med. 2017 Oct;5(10):771-772. [PubMed]

7. Falagas ME, Kopterides P, Siempos II. Attributable mortality of Acinetobacter baumannii infection among critically ill patients. Clin Infect Dis. 2006 Aug 01;43(3):389; author reply 389-90. [PubMed]

8. Vincent JL, Rello J, Marshall J, Silva E, Anzueto A, Martin CD, Moreno R, Lipman J, Gomersall C, Sakr Y, Reinhart K., EPIC II Group of Investigators. International study of the prevalence and outcomes of infection in intensive care units. JAMA. 2009 Dec 02;302(21):2323-9. [PubMed]

9. Jernigan JA, Hatfield KM, Wolford H, Nelson RE, Olubajo B, Reddy SC, McCarthy N, Paul P, McDonald LC, Kallen A, Fiore A, Craig M, Baggs J. Multidrug-Resistant Bacterial Infections in U.S. Hospitalized Patients, 2012-2017. N Engl J Med. 2020 Apr 02;382(14):1309-1319. [PMC free article] [PubMed]

10. Sievert DM, Ricks P, Edwards JR, Schneider A, Patel J, Srinivasan A, Kallen A, Limbago B, Fridkin S., National Healthcare Safety Network (NHSN) Team and Participating NHSN Facilities. Antimicrobial-resistant pathogens associated with healthcare-associated infections: summary of data reported to the National Healthcare Safety Network at the Centers for Disease Control and Prevention, 2009-2010. Infect Control Hosp Epidemiol. 2013 Jan;34(1):1-14. [PubMed]

11. Spivak ES, Hanson KE. Candida auris: an Emerging Fungal Pathogen. J Clin Microbiol. 2018 Feb;56(2) [PMC free article] [PubMed]

12. Weiner LM, Webb AK, Limbago B, Dudeck MA, Patel J, Kallen AJ, Edwards JR, Sievert DM. Antimicrobial-Resistant Pathogens Associated With Healthcare-Associated Infections: Summary of Data Reported to the National Healthcare Safety Network at the Centers for Disease Control and Prevention, 2011-2014. Infect Control Hosp Epidemiol. 2016 Nov;37(11):1288-1301. [PMC free article] [PubMed]

13. Park JH, Ryu SH, Lee JY, Kim HJ, Kwak SH, Jung J, Lee J, Sung H, Kim SH. Airborne fungal spores and invasive aspergillosis in hematologic units in a tertiary hospital during construction: a prospective cohort study. Antimicrob Resist Infect Control. 2019;8:88. [PMC free article] [PubMed]

14. Lemaire B, Normand AC, Forel JM, Cassir N, Piarroux R, Ranque S. Hospitalized Patient as Source of Aspergillus fumigatus, 2015. Emerg Infect Dis. 2018 Aug;24(8):1524-1527. [PMC free article] [PubMed]

15. Aitken C, Jeffries DJ. Nosocomial spread of viral disease. Clin Microbiol Rev. 2001 Jul;14(3):528-46. [PMC free article] [PubMed]

16. Ganczak M, Barss P. Nosocomial HIV infection: epidemiology and prevention--a global perspective. AIDS Rev. 2008 Jan-Mar;10(1):47-61. [PubMed]

17. Vincent JL, Bihari DJ, Suter PM, Bruining HA, White J, Nicolas-Chanoin MH, Wolff M, Spencer RC, Hemmer M. The prevalence of nosocomial infection in intensive care units in

Europe. Results of the European Prevalence of Infection in Intensive Care (EPIC) Study. EPIC International Advisory Committee. JAMA. 1995 Aug 23-30;274(8):639-44. [PubMed]

18. Klevens RM, Edwards JR, Richards CL, Horan TC, Gaynes RP, Pollock DA, Cardo DM. Estimating health care-associated infections and deaths in U.S. hospitals, 2002. Public Health Rep. 2007 Mar-Apr;122(2):160-6. [PMC free article] [PubMed]

19. Ling ML, Apisarnthanarak A, Madriaga G. The Burden of Healthcare-Associated Infections in Southeast Asia: A Systematic Literature Review and Meta-analysis. Clin Infect Dis. 2015 Jun 01;60(11):1690-9. [PubMed]

20. Ferioli M, Cisternino C, Leo V, Pisani L, Palange P, Nava S. Protecting healthcare workers from SARS-CoV-2 infection: practical indications. Eur Respir Rev. 2020 Mar 31;29(155) [PMC free article] [PubMed]