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Nosocomial infections: Epidemiology, prevention, control and Surveillance

Md Dilawar Shahnawaz [1,*], S Saquib Shahnawaz [1], Md Tauseef Reza [2], Shilpa Sharma [3], Raman Kumar [4] and Sandeep Kumar [5]

[1] *Rayat Bahra Professional University, University School of Allied & Healthcare Sciences, Hoshiarpur, Punjab, India.*
[2] *Hemvati Nandan Bahuguna Garhwal University, Department of Microbiology, Srinagar, Uttarakhand, India.*
[3] *Indo Global Group of Colleges, Department of Paramedical, New Chandigarh, Punjab, India.*
[4] *Guru Nanak Paramedical College, Department of Medical laboratory Science, SBS Nagar, Punjab, India.*
[5] *Sant Baba Bhag Singh University, Department of Life Sciences & Allied Health Sciences, Jalandhar, Punjab, India.*

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Abstract

Nosocomial infections, also known as healthcare-associated infections (HAIs), represent a significant global threat to patient safety, contributing to increased morbidity, mortality, and healthcare costs. These infections, which arise during medical care and were not present at the time of patient admission, include bloodstream infections, ventilator-associated pneumonia, urinary tract infections, and surgical site infections. In addition to viruses and fungi like Candida and Aspergillus, the main culprits are bacteria, including Staphylococcus aureus, Pseudomonas aeruginosa, Enterococcus species, and multidrug-resistant strains like MRSA. Transmission routes span from environmental sources and healthcare personnel to contaminated equipment. According to epidemiological data, low- and middle-income nations have a higher incidence of nosocomial infections. Although they remain a serious concern in high-income settings as well. Prevention strategies emphasize environmental hygiene, hand hygiene, staff training, proper use of medical devices, and robust waste management. Effective control requires integrated hospital-wide infection control programs supported by active laboratory involvement. In order to track infection patterns, direct preventative measures, and enhance patient outcomes, surveillance is essential. This review provides a comprehensive overview of the etiological agents, types, epidemiology, and evidence-based measures for the prevention, control, and surveillance of nosocomial infections.

Keywords: Nosocomial infections; Environmental hygiene; Pathogens; Transmission; Surfactant: Diet intake

1. Introduction

Health care-associated infection (HCAI), also known as nosocomial infection, 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]. Theoretically patients (hospitalized or outpatient), healthcare workers (HCWs) and visitors such as the family members of hospitalized patients can all acquire nosocomial infection, but it is more difficult to ascertain nosocomial infections in outpatients and visitors as they could also acquire the infection from the community [2]. The most frequent HCAIs include urinary tract infections (UTI), surgical site infections (SSI), bloodstream infections (BSI) and hospital-acquired pneumonia (World Health Organization, 2011) [3,4]

* Corresponding author: Md Dilawar Shahnawaz

Those are acquired independently during medical operations and are connected to devices, but the burden of nosocomial infections is also thought to be significantly increased by the spread of microorganisms among hospitalized patients [5]. Hospital-acquired infections (HAIs) occur globally in developed and developing countries with high morbidity and mortality For example in the USA and Europe, HAIs are among the leading cause of death [6, 7]. Bacteria are responsible for 90% of Nis, while mycobacterial, viral, fungal, or protozoal agents are less frequently implicated.

The bacteria that commonly cause nosocomial infections include Staphylococcus (S.) aureus, Streptococcus spp., Bacillus cereus, Acinetobacter spp., coagulase negative staphylococci, enterococci, Pseudomonas (P.) aeruginosa, Legionella and members of the Enterobacteriaceae family such as Escherichia (E.) coli, Proteus mirabilis, Salmonella spp., Serratia marcescens and Klebsiella pneumoniae. However, E. Coli, S. Aureus, enterococci, and P. Aeruginosa have been the nosocomial infections most commonly reported [8,9].

Hospital-acquired infections are a major challenge to patient safety. Device-associated infections (i.e., ventilator associated pneumonia, catheter-associated urinary tract infection, and central catheter-associated bloodstream infection) account for 25.6% of all health care-associated infections; together, device-associated infections and surgical-site infections (21.8%) account for 47.4% of all health care-associated infections (239 of 504 infections). Nosocomial infections can have significant negative consequences, including extra An estimated 721800 hospital-acquired illnesses happened in the United States in 2011 [10].

hospitalization days, additional costs, and even deaths, depending on the site of infection. These consequences and associated costs can be substantial, and it is important to identify patients at highest risk for infection in order to prioritize prevention and control efforts [11].

2. Agents of Nosocomial Infections

2.1. Bacteria

Although there are multiple species in the genus Staphylococcus, S. Aureus is by far the most significant nosocomial pathogen. [12]. It is the primary cause of lower respiratory tract infections and surgical site infections and the second leading cause of nosocomial bacteremia, pneumonia, and cardiovascular infections. One of the main causes of nosocomial infections is P. Aeruginosa. It can temporarily colonize hospitalized patients' gastrointestinal and respiratory tracts, especially those receiving broad spectrum antibiotic treatment, being near respiratory therapy equipment, or being in the hospital for a long time [13].

P. aeruginosa is responsible for about 10% -20% of nosocomial infections as bacteraemia and sepsis in ICU, cystic fibrosis, pneumonia, urinary tract infections, burn infection and wound infection [14]. Infections obtained in hospitals are also linked to enterococci. These are regarded as a natural component of the human genitourinary and gastrointestinal tract flora. Enterococcus faecalis and E. Faecium are the two species that cause the bulk of human enterococcal infections; other species are rare.

The most frequent nosocomial infections caused by these organisms are pelvic and intra-abdominal infections, which are followed by urinary tract infections (linked to the use of instruments and the administration of antibiotics). In addition, they can result in endocarditis, neonatal sepsis, bacteremia, surgical wound infection, and infrequently, meningitis. Eighty to ninety percent of infections are caused by E. Faecalis, with E. Faecium coming in second (10–15%) [15].

One of the main risk pathogens linked to the emergence of antimicrobial resistance (AMR) is Methicillin-resistant Staphylococcus aureus (MRSA).

The emergence of AMR in S. aureus is well documented and the species has proven particularly adept at evolving resistance in the face of new antibiotic challenges. The introduction of penicillin in the 1940s heralded a revolution in the treatment of infectious diseases. However, at the same time as its use was becoming more widespread following advances in the scaling up of production, evidence of penicillin resistance in S. aureus was already being uncovered [16].

2.2. Virus

Viruses are considered as the most common cause of infectious diseases acquired within indoor environments. Human seasonal influenza viruses are a common cause of respiratory tract infections both in the community and in hospitals

[17] Nosocomial viral infections are most dangerous in young, elderly, and immunocompromised people and are commonly spread by respiratory droplets, fecal-oral pathways, direct contact, or contaminated surfaces.

[18]. Common viruses implicated in nosocomial infections include respiratory viruses like influenza, RSV, adenoviruses, and coronaviruses (e.g., SARS-CoV-2), as well as gastrointestinal viruses such as norovirus and rotavirus. Bloodborne viruses: including hepatitis B virus (HBV), hepatitis C virus (HCV), and human immunodeficiency virus (HIV), typically transmitted through unsafe injections or blood exposure. During the COVID-19 pandemic, SARS-CoV-2 emerged, drawing attention to nosocomial viral transmission like never before. Research reported hospital epidemics brought on by a lack of ventilation, asymptomatic carriers, and insufficient personal protective equipment (PPE) [19].

2.3. Fungus

Nosocomial fungal infections, although less common than bacterial infections, have become a growing concern in healthcare settings due to increasing numbers of immunocompromised patients, broad-spectrum antibiotic use, and invasive procedures. Candida species, especially Candida albicans, are the most common cause of nosocomial fungal infections. Non-albicans species, such as Candida glabrata, Candida parapsilosis, and Candida auris, are next in line [20]. C. auris, in particular, has drawn global attention due to its multidrug resistance, ability to persist on surfaces, and propensity to cause outbreaks in healthcare facilities [21]. Additionally important nosocomial infections are Aspergillus species, particularly in transplant and neutropenic patients. Outbreaks in hematology and oncology units have been caused by airborne transfer of Aspergillus spores, especially during hospital construction or remodeling [22].

Preventive measures include stringent infection control practices, environmental monitoring, antifungal stewardship, and the use of HEPA filters in high-risk units. Surveillance and early identification are critical to managing these infections and curbing transmission within hospitals [23].

3. Types of nosocomial infections

The most frequent types of infections include central line associated bloodstream infections, catheter-associated urinary tract infections, surgical site infections and ventilator-associated pneumonia. A brief detail of these is given below:

3.1. Central line-associated bloodstream infections (CLABSI)

With a 12%–25% fatality rate, CLABSIs are a kind of nosocomial infection [24]. Central line catheters are used to deliver medications and fluids, but long-term use can result in dangerous bloodstream infections that impair health and raise medical expenses [25]. Even though the number of CLABSI in US hospitals decreased by 46% between 2008 and 2013, an estimated 30,100 CLABSI still happen annually in ICU and acute facility wards in the US [26].

3.2. Catheter associated urinary tract infections (CAUTI)

Globally, CAUTI is the most common nosocomial infection. In 2011, acute care hospital statistics showed that UTIs accounted for almost 12% of all infections. The patients' endogenous native microbiota is the etiology of CAUTIs. Internally placed catheters act as a pathway for bacterial entry, while the catheter's imperfect drainage keeps a certain amount of urine in the bladder, stabilizing the bacterial residence. CAUTI can lead to complications like orchitis, prostatitis, and epididymitis in men, as well as pyelonephritis, cystitis, and meningitis in all patients [27, 28].

3.3. Surgical site infections (SSI)

SSIs are nosocomial infections that affect 2% to 5% of surgical patients. These are the second most prevalent kind of nosocomial infections, primarily brought on by Staphylococcus aureus, which can lead to extended hospital stays and even death. The patient's endogenous microbiota is the source of the infections that cause SSI. Depending on the method and surveillance standards employed, the incidence could reach 20% [29, 30].

3.4. Ventilator associated pneumonia (VAP)

VAP, or nosocomial pneumonia, affects 9–27% of patients who are on a ventilator with mechanical assistance. Usually, it happens 48 hours after tracheal incubation. Ventilation is linked to nosocomial pneumonia in 86% of cases. Common signs of VAP include bronchial noises, leukopenia, and fever [31–33]. This type of pneumonia affects 9% to 27% of patients on assisted breathing, and VAP has been recognized globally as a possible leading cause of death [34].

4. Epidemiology

Nosocomial infections affect millions annually, with prevalence rates of 5–7% in high-income countries and up to 5% in LMICs, particularly impacting ICUs, surgical wards, and neonatal units due to factors like invasive procedures, wound exposure, and vulnerable immune systems [35]. 6.5% of hospitalized patients in Europe had at least one HAI, according to a point prevalence survey carried out by the European Centre for Disease Prevention and Control (ECDC) [36]. Due to increased infection control measures, the prevalence in the United States decreased from prior years to 3.2% in 2015, according to a national study conducted by the Centers for Disease Control and Prevention (CDC) [37]. In England alone, 300,000 patients receive a diagnosis of HCAI each year, costing the NHS an estimated £1 billion. This information comes from NICE.

Cross-contamination within the hospital or contamination of other materials and equipment could be the cause of this. The many hospital-acquired diseases and the pathogenic microbes that cause them will be discussed in this article. To guarantee hospital safety and avoid HCAIs, further research and practice modifications are required because HCAIs raise morbidity, mortality, length of hospital stays, and expenses [38].

5. Prevention

Being a significant cause of illness and death, nosocomial infections need to be prevented from the base line so that their spread can be controlled.

5.1. Transmission from environment

The greatest setting for the pathogenic organism to thrive in is an unsanitary one. Food, water, and air can become polluted and spread to patients while they are receiving medical care. Policies must be in place to guarantee that the walls, floors, windows, beds, bathtubs, toilets, Controle, and other medical equipment are cleaned and cleaned with cleaning products.

Proper ventilated and fresh filtered air can eliminate airborne bacterial contamination. Regular check of filters and ventilation systems of general wards, operating theatres and ICUs must be maintained and documented. Infections attributed to water are due to failure of healthcare institutions to meet the standard criteria. Microbiological monitoring methods should be used for water analysis. Infected patients must be given separate baths. Improper food handling may cause food borne infections. The area should be cleaned and the quality of food should meet standard criteria.

5.2. Transmission from staff

Healthcare personnel can spread infections. Healthcare workers have an obligation to participate in infection control. Everyone needs personal hygiene; thus, employees should practice it. After coming into touch with infected patients, it is necessary to decontaminate your hands with the appropriate hand disinfectants. Sterilized equipment and safe injection procedures should be employed. Healthcare delivery requires the use of masks, gloves, head coverings, or a suitable clothing.

5.3. Hospital waste management

Hospital waste should be handled carefully since it may serve as a reservoir for germs. Hazardous waste makes around 10–25% of the garbage produced by healthcare facilities. It is best to keep infectious medical waste in a restricted-access area. Waste from surgeries, infected people, diagnostic labs, and waste contaminated with blood or sputum must be disposed of separately, as must waste with a high concentration of heavy metals. Cleaners and healthcare personnel should be made aware of the risks associated with the waste and how to properly manage it [39].

5.4. Protein rich diet intake

Adequate protein intake is crucial for managing nosocomial (hospital-acquired) infections by supporting the immune system, facilitating tissue repair, and building new cells. Proteins are made up of amino acids [40-42]. A balanced approach is key, as both insufficient and excessive protein can be detrimental. Patients with infections, especially critically ill ones, have higher protein needs, but the optimal amount can vary based on their condition.

5.5. Control of nosocomial infections

Despite of significant efforts made to prevent nosocomial infections, there is more work required to control these infections. In a day, one out of 25 hospital patients can acquire at least a single type of nosocomial infection [43].The

success of the hospital's infection control efforts hinges to a large extent on the active involvement of the laboratory in all aspects of the infection control program. Laboratory personnel should understand why infection control is necessary, the approaches being taken by the hospital's infection control program to meet its objective to reduce nosocomial infections, and how the laboratory can support and cooperate with the program [44]. Programs to prevent these infections should be developed by healthcare institutions. In order to fulfil their responsibility in infection control, hospital administration, staff, and patients must consider such initiatives.

5.6. Role of surfactant in prevention of nosocomial infections

Pulmonary surfactant plays a vital role in preventing nosocomial infections by serving as a physical barrier against pathogens, enhancing the body's natural microbial clearance mechanisms, and regulating inflammatory responses. A surfactant is an amphiphilic compound that reduces the surface tension of a liquid by having both a water-attracting (hydrophilic) head and a water-repelling (hydrophobic) tail [45-54]. It forms micelles at a specific concentration known as the critical micelle concentration (CMC) [55-62]. Its primary functions include reducing surface tension to prevent alveolar collapse, minimizing fluid accumulation, and improving mucociliary transport to facilitate pathogen removal. Additionally, the immunomodulatory properties of surfactant help control the body's response to infectious agents, thereby protecting the lungs from infection.

5.7. Role of nanomaterial/emulsion on prevention of nosocomial infections

Nanomaterials and nanoemulsions help prevent nosocomial infections by acting as direct antimicrobial agents, preventing biofilm formation, and serving as delivery systems for traditional drugs [63]. Nanomaterials are the substance having particles or constituents of nanoscale dimensions, or one that is produced by nanotechnology. Nanomaterials can physically damage bacteria, while nanoemulsions can inhibit virulence and biofilm formation on surfaces. Together, they offer novel strategies to combat antibiotic-resistant bacteria, which is crucial for controlling hospital-acquired infections [64-66].

5.8. Surveillance

Surveillance is a cornerstone of infection prevention and control (IPC) programs in healthcare settings, playing a crucial role in reducing nosocomial (hospital-acquired) infections (HAIs).

The methodical gathering, evaluation, interpretation, and distribution of health data pertaining to HAIs are all necessary for effective surveillance. It makes it possible to identify infection trends, diagnose outbreaks early, and assess IPC measures. Active surveillance, in which skilled workers proactively gather infection data, and passive surveillance, which depends on regular reports from clinical professionals, are the two primary forms of surveillance.

Active surveillance is considered more accurate and reliable, albeit more resource-intensive [67]. Standardized surveillance definitions, such as those provided by the Centers for Disease Control and Prevention (CDC) through the National Healthcare Safety Network (NHSN), are essential to ensure consistency and comparability of data across institutions [68]. Electronic health records and automated alert systems are frequently incorporated into modern surveillance systems, which can enhance the promptness and precision of data collecting [69]. The monitoring procedure works best when it is incorporated into a larger infection control plan that also addresses environmental cleanliness, antimicrobial stewardship, and staff education [70].

6. Conclusion

Globally, nosocomial infections remain a serious threat to patient safety and healthcare systems. These infections continue to be a major source of avoidable disease and mortality, especially in intensive care units and surgical wards, despite improvements in medical care and infection control procedures. Understanding the epidemiological trends, causative agents, and high-risk areas is essential for targeted interventions. Prevention efforts must be multifaceted, involving strict adherence to hygiene protocols, effective hospital waste management, antimicrobial stewardship, and environmental controls. Furthermore, surveillance systems are essential for detecting outbreaks early and assessing how well infection control measures are working. Moving forward, ongoing education, innovation in healthcare infrastructure, and interprofessional collaboration will be vital in reducing the burden of hospital-acquired infections and ensuring safer healthcare environments for both patients and staff.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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