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Navigating nosocomial infection in ICU patients of all age: a review of epidemiology, pathophysiology, diagnostic approaches & prevention strategies

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Abstract
As invasive procedures and devices are common in ICUs, patients there are more susceptible to healthcare-acquired infections (HAI) because of their advanced age, comorbidity, induced immunosuppression, and weakness. It is reasonable to draw the conclusion that nosocomial infections raise the risk of death in critically sick patients, even though a direct correlation between nosocomial infection and mortality in intensive care unit (ICU) patients has not always been proven specifically. More accurate analysis shows that this effect is extremely probable for pneumonia, unlikely for bacteremia, and uncertain for urinary tract infection (UTI). The length of staying in the intensive care unit (ICU) increases the risk of infection and the associated risk; additionally, the bacterial etiology influences the risk. The effect is greater in less critically ill patients, most likely due to the fact that the underlying disease severity is still the most important factor. Staphylococcus aureus, Pseudomonas aeruginosa, Candida species, Escherichia coli, and Klebsiella species are among the common pathogens. The use of antibiotics has created selective pressure, and health personnel have been the source of the spread of antimicrobial resistance, which is generally on the rise. Good antibiotic use, infection control, sterile equipment, and hand hygiene can all help prevent infection.

Keywords: Antimicrobial resistance, bacteremia, immunosuppression, intensive care unit, nosocomial infection

Introduction
Nosocomial infections, sometimes referred to as hospital-acquired infections, are illnesses that patients get while undergoing medical care; they are usually not present when they are admitted [1]. Intensive care units (ICUs) have a 2–5 times higher infection rate than the overall inpatient population, indicating a notable increase in the prevalence of these illnesses there [2]. This is probably because of things like how serious patients' diseases are, how invasive technologies are used, and how long patients stay in the hospital. These infections have serious side effects, including higher rates of morbidity and death as well as longer hospital admissions, all of which can increase the expense of healthcare. From a medicolegal standpoint, hospitals and employees might be sued because patients or their families might blame them for the infections [3]. Preventive measures are crucial in healthcare settings, since studies indicate that hospitals with strong nosocomial infection surveillance programs can reduce infection rates by approximately one-third [4].
Healthcare-associated infections (HAIs), commonly referred to as nosocomial infections, pose a serious threat to patient safety because of their effects on morbidity, mortality, and the financial burden they place on both patients and healthcare systems. They can have an impact on patients as well as healthcare personnel and can happen in a range of healthcare settings. These infections can be brought on by a range of pathogens, such as bacteria, viruses, and fungi, and are frequently associated with invasive procedures, medical equipment, and operations. Nosocomial infections are associated with increased mortality, morbidity, and lengthier hospital stays, especially in the critical care unit (ICU). The development of these illnesses must occur more than 48 hours after admission; prevalence rates range from 9% to 37%. Improving patient outcomes and reducing antibiotic resistance need early diagnosis, adequate treatment, and preventive measures [5].

HAIs impact 3.2% of hospitalized patients in the United States and 6.5% of patients in the European Union, depending on the region. However, because of insufficient surveillance mechanisms, global numbers are still unknown [6]. Infection prevention programs play a vital role in controlling and lowering the prevalence of these illnesses, particularly when dealing with issues such as multi-drug resistance organisms [7].

Epidemiology of HAIs amongst ICU admitted patients

In intensive care units (ICUs), nosocomial infections represent a serious risk to patient outcomes and are associated with rising healthcare costs. The type of intensive care unit, patient demographics, and medical procedures all affect the occurrence of these illnesses. Studies reveal that between 10 and 20 percent of hospitalized patients get a nosocomial infection during their stay; common infections in intensive care units (ICUs) include bloodstream infections, pneumonia, urinary tract infections, and surgical site infections. Multidrug-resistant organisms commonly cause these infections, which makes treatment more difficult and raises fatality rates. Comprehending the nosocomial infection epidemiology is essential for formulating efficacious prevention and control tactics. Healthcare practitioners can greatly reduce the effect of these illnesses in intensive care units by evaluating infection rates, determining risk factors, and putting strict infection control measures in place [8].

Numerous patients worldwide suffer from nosocomial infections, which raise mortality and have a costly burden on healthcare systems. Due to a lack of trustworthy data and surveillance systems, the true worldwide burden of healthcare-associated infections (HAI) is still unknown; nonetheless, a number of epidemiologic studies demonstrate comparatively consistent outcomes in monitoring programs. The frequency of at least one HAI varies according to the kind of care environment, according to several studies conducted among European hospitals: 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 institutions [9]. It is estimated that in 4 acute care and long-term care facilities in the European Union, there are about 8.9 million unique HAI incidents per year. ICU-acquired infection prevalence was found to be 20.6% in the European Prevalence of Infection in Intensive Care (EPIC) [10].

According to a 2015 survey, the prevalence of HAI among hospitalized patients in the US was 3.2%, considerably lower than the 4% seen in a 2011 study [14]. The same study revealed that of HAI in US health institutions, critical care locations accounted for 36.4%, ward or nursery locations for 57.5%, step-down or specialist care units for 6.1%, and mixed acuity locations (varying degrees of acute care) for 6.1%. According to a previous study, the highest rates of HAI acquisition were found in high-risk neonate nurseries, well-baby nurseries, adults and children outside of ICUs, and ICU patients [15]. In US hospitals, there were an estimated 687,200 HAI cases in 2015, impacting 633,300 patients [14]. Compared to 2002 statistics, which estimated that there were 1.7 million HAI cases annually in US hospitals, these numbers are encouraging [11].

There seems to be a greater endemic burden of HAI in underdeveloped nations. The majority of HAI cases, which occur as ventilator-associated pneumonia (VAP) and neonatal infections in intensive care units, are 15.5%, according to a pooled review of data from developing nations [3]. 9.1% was the total prevalence of HAI in Southeast Asian nations, according to a systematic review [12].

Immunosuppression status in ICU patients

ICU patients frequently have weakened immune systems as a result of underlying medical conditions, traumatic experiences, or extended hospital stays. They are susceptible to nosocomial infections because of their heightened vulnerability to infection. Immunosuppression in intensive care unit (ICU) patients can be caused by a number of things, such as severe sickness, immunosuppressive drugs and corticosteroids, extended mechanical ventilation, malnourishment, and surgical operations. When these elements come together, the immune system may be considerably weakened, leaving patients more susceptible to infection. Thus, it is essential to comprehend how immunosuppression and nosocomial illness interact [13, 14].

Pathophysiology of Nosocomial infection

There are various ways that pathogens linked to healthcare-associated illnesses (HAI) can spread. When organisms come into direct or indirect contact with one another, contact is the most frequent mode of transmission. Clostridium difficile, rotavirus, ESBL-producing Gram-negative organisms, multidrug-resistant bacteria (like MRSA), and VRE are common germs spread in this manner. When big droplets (larger than 5 microns) travel less than 3 feet, droplet transmission takes place, transferring bacteria from the respiratory system. Neisseria meningitidis, Bordetella pertussis, and influenza are among the pathogens that can be spread via droplets. Through the use of tiny, long-distance-traveling droplets (less than 5 microns), organisms can propagate through the air. Measles, SARS-CoV-2, TB, and the chickenpox virus are a few examples. Central Line-Associated Blood Stream Infection (CLABSI) [15].

Central line-associated blood stream infection is the most avoidable kind of HAI and happens in the context of a central venous line (CVC). CVC affects 24% of non-ICU patients and 55% of ICU patients in the US [17]. Usually, CLABSI happens when skin bacteria spread along the catheter's outside and into the intravascular area. Other ways that CLABSI can happen include hematogenous seeding or contamination of the CVC during the insertion or modification procedure. The virulence traits of the bacteria and fungal pathogens that cause CILABSI and CAUTI often lead to the development of biofilms, which improves adhesion and multiplication on external devices [16]. According to a recent study, the common organisms linked to CLABSI were E. coli (8%), Bacteroides species (6%), S. aureus (23%), Candida species (13%), coagulase-negative Staphylococcus (12%), Enterococcus species (12%), and Streptococcus species (12%). Coagulase-negative Staphylococci continue to be identified by other investigations as the most prevalent organism, nevertheless [8, 17]. Antimicrobial resistance is a major issue with these infections [18].

Catheter and host factors are two categories of CLABSI risk factors. Immunocompromised conditions such as long-term sickness, neutropenia, starvation, parenteral nutrition, severe age, and bone marrow transplants are examples of host factors. Extended hospital stays prior to catheterization,

longer catheterization times, multiple lumen CVCs, different types of catheter materials, multiple CVCs, urgent insertions, and absence of sterile barriers or breaches in aseptic technique are all considered catheter factors. Whether femoral CVC is more likely to result in CLABSI than subclavian or jugular locations is a topic of some disagreement [19].

The most avoidable healthcare-associated illness (HAI) is Central Line-Associated Blood Stream illness (CLABSI), which affects patients who have a central venous catheter (CVC). Approximately 55% of ICU patients and 24% of non-ICU patients in the United States have a CVC. Although hematogenous seeding and contamination during catheter insertion or handling are other possible causes, CLABSI often arises from skin bacteria migrating along the catheter's exterior surface toward the bloodstream. The bacteria that cause catheter-associated urinary tract infections (CAUTI) and CLABSI frequently include virulence characteristics that encourage the formation of biofilms, which help the pathogens stick to devices and facilitate infection. The bacteria Staphylococcus aureus (23%), Candida species (13%), coagulase-negative staphylococci (CoNS) (12%), Enterococcus species (12%), Streptococcus species (12%), Escherichia coli (8%), and Bacteroides species (6%), were found to be common CLABSI pathogens in a recent study. However, other studies continue to identify coagulase-negative staphylococci as the most common organism. One major problem with these pathogens is their resistance to antibiotics [20, 21].

There are two categories of risk factors for CLABSI: host-related and catheter-related. Immunocompromised conditions such as long-term sickness, neutropenia, starvation, reliance on parenteral nutrition, extreme age, and bone marrow transplantation are examples of host factors. Extended hospital stays before catheterization, protracted catheter use, multiple lumen CVCs, catheter material type, multiple CVCs, urgent insertion, and sterile procedure breaches are examples of catheter factors. The question of whether femoral CVCs have a higher risk of CLABSI than subclavian or jugular locations is up for dispute [22].

Diagnostic measures to Evaluate Nosocomial Infection

Improving patient outcomes and controlling nosocomial infections require early and precise diagnosis. This calls for an all-encompassing strategy that incorporates imaging investigations, laboratory testing, and clinical assessment. Evaluating a patient's symptoms, indicators, and medical history is known as clinical assessment. Antibiotic susceptibility testing and identification of the causal organism are aided by laboratory testing, such as the culture process. To evaluate infection locations, imaging methods such as CT scans or chest X-rays are utilized. After a diagnosis, it's critical to assess the infection's severity, take patient risk factors into account, and create a customized treatment plan that will be continuously monitored and adjusted [23].

The kind of infection, particular risk factors, and presenting symptoms all play a role in the differential diagnosis of healthcare-associated infections (HAIs). The distinction between HAIs and community-acquired infections (HAIs) is critical since the two types of illnesses frequently include distinct bacteria and patterns of antibiotic resistance. Appropriate management and treatment of the infection are guided by accurately determining its origin [24].

In order to make this distinction, the time of symptom onset is crucial. Certain healthcare exposures, such as the use of urinary catheters, central venous catheters (CVCs), or broad-spectrum antibiotics, can lead to the development of certain illnesses. For example, the emergence of symptoms in the presence of a CVC or 48 hours after its removal could point to a source associated to healthcare. Moreover, a number of HAIs can resemble community-acquired infections, so it's important to carefully consider the timing, clinical presentation, and diagnostic tests to ensure accurate diagnosis and management. Examples of these infections include central line-associated bloodstream infections (CLABSI), catheter-associated urinary tract infections (CAUTI), surgical site infections (SSI), and hospital-acquired pneumonia (HAP) [25].

With situations like CLABSI, bacteremia without a CVC leads to a search for alternative causes, such as pneumonia or wound infection; with CAUTI, however, it is crucial to distinguish between UTIs that are community-acquired and those that are catheter-associated. Surgical site infections often develop within 30 to 90 days post-surgery, and diagnosis involves both clinical indicators and diagnostic criteria such purulent discharge or positive cultures [26]. The diagnosis of ventilator-associated pneumonia (VAP) and other healthcare-associated pneumonia (HAP) is made on the basis of the start of symptoms following 48 hours of hospitalization or ventilation. Last but not least, identifying other infectious and noninfectious causes of diarrhea, such as viral infections or antibiotic-associated diarrhea brought on by bacteria like Salmonella or S. aureus, is necessary in order to treat hospital-acquired C. difficile infection (HO-CDI). Irritable bowel syndrome, ischemia disorders, and inflammatory bowel illness may potentially be included in the differential diagnosis for HO-CDI. Apart from these primary classifications, there exist other uncommon HAIs that might impact diverse systems; however, the crucial aspect persists in identifying and assessing symptoms that follow medical procedures [27, 28].

Prognosis

Healthcare-associated infections (HAI) have varying prognoses depending on the pathogen implicated, the kind of infection, and the severity of the patient's sickness. Although there is a lack of adequate surveillance and analysis to determine global rates of morbidity and mortality, a number of studies have offered estimates of the burden worldwide. The 30-day mortality rate ascribed to HAI varies greatly; depending on the population under study, some studies predict a crude mortality rate of approximately 10%, while others suggest crude mortality rates ranging from 12% to 80%. Even once prognostic factors are taken into consideration, critically sick individuals typically have higher excess mortality. According to an international study, patients with HAI had ICU death rates of 25%, while individuals without the illness had rates of 11% [29].

Patients with HAI had overall hospital death rates that were twice as high (30%) as those without (15%). According to estimates, the United States saw 98,987 HAI-related deaths in 2002. The most common causes were bloodstream infections, pneumonia, surgical site infections (SSI), and

urinary tract infections (UTI). HAI has a major effect on hospital stay duration, with additional LOS average 12 days, though it might vary depending on the type of infection [30]. An longer LOS of up to 25.6 days may be experienced by patients with multiple HAIs. In the US, patients with HAI were observed to have an additional length of stay (LOS) of 26.30 days, while patients without HAI had LOS of 5.69 days. This extended stay in developing nations varies from five to twenty-three days. The most expensive types of HAI are central line-associated bloodstream infections (CLABSI), ventilator-associated pneumonia (VAP), and surgical site infections (SSI) [31].

Preventive measure of HAIs

A multifaceted strategy including strict infection control procedures, attentive surveillance, and proactive interventions is needed to prevent nosocomial infections. Using soap and water or an alcohol-based hand sanitizer before and after patient contact and procedures is one of the most important preventive strategies for healthcare personnel. It's also critical to put isolation protocols in place, such as those for patients with multidrug-resistant pathogens. To reduce germs and stop antibiotic resistance, comprehensive environmental cleaning and prudent antibiotic use by management programs are also required. To keep a safe healthcare environment, these procedures must be continuously monitored and improved [32].

Conclusion

Nosocomial infections remain a serious concern in intensive care units, hurting patient outcomes and healthcare costs. For successful control and prevention methods to be implemented, it is imperative to comprehend the epidemiology of these illnesses, the variables that contribute to their development, and the function of the microbiome. Optimizing patient care and reducing the incidence of nosocomial infections requires early diagnosis, thorough evaluation, and strict infection control measures. Healthcare providers may make the ICU a safer and more efficient place for patients by adopting a multifaceted strategy that incorporates hand hygiene, isolation precautions, environmental cleaning, antibiotic stewardship, and ongoing monitoring. To further lower the frequency and consequences of nosocomial infections in this critical care setting, research and development in infection control techniques are essential. These findings can now be applied in planning a program to monitor for nosocomial infection in our ICU facility as an initial step toward a better infection management approach.

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