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The role of the Hospital environment in the Staphylococcal infections

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ABSTRACT

Staphylococcus spp. are common causes of healthcare-associated infections (HAIs) that can be transmitted through various routes. The hospital environment can serve as a reservoir for these pathogens. This review examines the role of environmental contamination in the transmission of Staphylococcus spp. infections and how to prevent and control it. It describes the definition of the hospital environment and its potential sources of contamination, including surfaces, fomites, air, and water. It summarizes the evidence on the frequency and extent of environmental contamination by *Staphylococcus spp*., especially methicillin-resistant S. aureus (MRSA), and its impact on HAIs. It also discusses strategies to reduce environmental contamination, such as cleaning, disinfection, hand hygiene, isolation precautions, and decolonization. It highlights the challenges and gaps in knowledge that need to be addressed to improve infection prevention and control practices. The review concludes that environmental contamination plays a significant role in the transmission of *Staphylococcus spp*. infection and that more research is needed to evaluate the effectiveness of interventions to reduce it.

دور بيئة المستشفى في عدوى بكتيريا المكورات العنقودية.

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الكلمات المفتاحية:
التلوث البيئي
المكورات العنقودية
بيئة المستشفيات
عدوى المستشفيات
مكافحة العدوى

الملخص

تعد المكورات العنقودية من الأسباب الشائعة للعدوى المرتبطة بالرعاية الصحية (HAIs) والتي يمكن أن تنتقل عبر طرق مختلفة. يمكن أن تكون بيئة المستشفى بمثابة خزان لمسببات الأمراض، تبحث هذه المراجعة في دور التلوث البيئي في انتقال المكورات العنقودية وكيفية الوقاية منها ومكافحتها. يصف تعريف بيئة المستشفى ومصادر التلوث المحتملة، بما في ذلك الأسطح والهواء والماء. ويلخص الدليل على تواتر ومدى التلوث البيئي من قبل المكورات العنقودية وخاصة المكورات العنقودية الذهبية المقاومة للميثيسيلين (MRSA)، وتأثيرها على الرعاية الصحية. كما يناقش استراتيجيات الحد من التلوث البيئي، مثل التنظيف والتطهير ونظافة اليدين واحتياطات العزل وإنهاء استعمار هذه الممرضات. يسلط الضوء على التحديات والفجوات في المعرفة التي تحتاج إلى معالجة لتحسين الوقاية من العدوى وممارسات السيطرة عليها. تستنتج المراجعة أن التلوث البيئي يلعب دورًا مهمًا في انتقال عدوى المكورات العنقودية وأن هناك حاجة إلى مزيد من البحث لتقييم فعالية تدخلات الحماية للحد من عدوى المستشفيات.

Introduction

Healthcare-associated infections (HAIs) are a Worldwide issue [1], [2]. They cause around 2.5 million infections each year and are linked to higher of rates of morbidity, mortality, and healthcare costs[3]–[5].

The *Staphylococci* are Gram-positive spherical cells and typically, from irregular clusters that resemble grape, there are at least 55 species within the *Staphylococcus* genus [6]. They are separated in to two major groups based their ability to clot (coagulate) blood plasma

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through the production of staphylocoagulase [7]. Coagulase-positive *Staphylococci* (CoPS) include pathogenic species such as; *S. aureus*, while coagulase negative-*Staphylococci* (CoNS) include species that are normally found on human skin such as *Staphylococcus epidermidis* [8]. As well *Staphylococci* can be found everywhere in the environment, and are a normal part of the flora in soil, water, skin and mucous membranes of warm-blooded animals, they have also been commonly found in various food products such as dairy and meat [9]. *S. aureus* is responsible for a wide range of infections that can be acquired both in the community and hospitals, these include infections of the skin and soft tissues, surgical site, bone and joint, it is also a frequent cause of hospital-acquired bacteraemia and respiratory tract infections [8], [10], [11]. Additionally, *S. aureus* is a significant food-borne pathogen often linked to raw unpasteurized milk from dairy cattle with *Staphylococcal*-associated mastitis [9], [12]. Around 30% of healthy adults have been reported to carry *S. aureus* in their noses [11]. CoNS are commonly found on human skin and contribute to the flavor and aroma of fermented foods such as cheese and sausage, however, there has been a recent increase in hospital-acquired infections involving CoNS [8, 9, 13]. The spread of antibiotic-resistant *Staphylococci* is a major public health issue as these bacteria can easily spread in the environment. Infections caused by methicillin-resistant *Staphylococcus aureus* (MRSA) have been on the rise globally for the past two decades [10], [14]. Multiple drug-resistant *S. aureus* have also been found in food [15], [16], water and biofilms [17], human nasal mucosa [18], and in clinical cases and livestock [19], [20]. Methicillin-resistant *Staphylococcus Epidermidis* (MRSE) has also become more common in hospital-acquired infections [8]. Additionally, multiple antibiotic-resistant CoNS have been found in food, drinking water and wastewater [21], [22].

Survival of *Staphylococci* in nature

Staphylococci, especially strains resistant to antibiotics, have been a major concern for public health authorities due to their ability to survive for long periods in various environments, *Staphylococci* can be adapt to different environmental conditions, so in 2008 Tolba et al. showed that they can live for weeks in recreational fresh and salt waters [23]. MRSA was also found to survive on fomite for up to 60 days; this suggests that good hygiene practices are essential for the controlling hospital and community-acquired *Staphylococcal* infections [24].

Hospital environments

S. aureus, especially antibiotic-resistant strains still continue as a major source of hospital acquired infections [8], [10]. The rate at which CoNS are associated with hospital infections is rising, particularly catheter-related bacteraemia and endophthalmitis after surgery [8], [13]. The bacteria are shed by patients and healthcare workers (HCWs) onto surfaces, dust, dirt and bio-aerosols that can also be potential sources of the organisms in the hospital environment, this may lead to widespread contamination and colonization by the bacteria, especially MRSA [25]–[27]. It was found that removing dirt in the hospital environment could impact the control of *Staphylococci*, especially MRSA [25]. Additionally, hydrogen peroxide vapour was very effective in eliminating MRSA that were not removed by conventional cleaning methods in healthcare settings [28].

Epidemiology of infections:

According to Many studies, the hospital environment can play a role in spreading important nosocomial pathogens to patients, one of these nosocomial pathogens is MRSA [29]–[34]. However, in Libya, this issue has not been adequately studied, but the studies we obtained prove that there is a relative increase in the spread of *Staphylococcus spp*. in the hospital environment [35], [36]. MRSA can be easily found in the hospital environment, especially around colonized or infected patients, *Staphylococci* can be persist in the environment for 7 days to 7 months [37] and the infection's retention and transfer depend on the surface's [38].

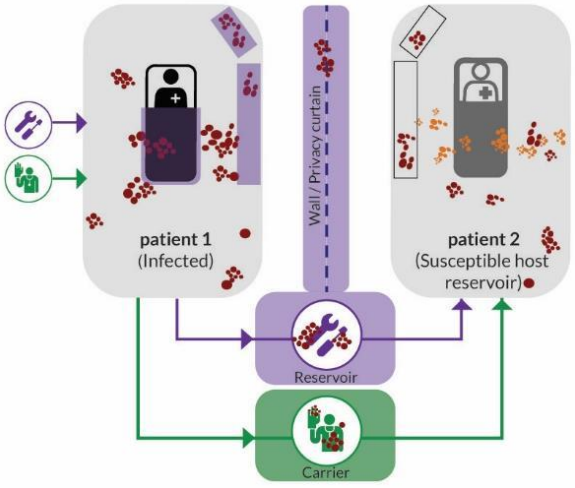
A preventable risk factor for getting infected with MRSA is being hospitalized in a room that was previously used by infected patients, the surfaces that are closer to the patient, such as bed bars and header, bedside table, taps and handles in wards ("high-touched surfaces") are more likely to be infected [39].

Boyce et al [40] showed in 1997 that MRSA presence on surfaces near patients could lead to HCWs contaminate their hands and gloves by touching these surfaces. HCWs are often in close contact with environmental surfaces in patients' rooms and can easily contaminate their hands and/ or gloves this way. It has been shown that MRSA can contaminate HCWs' hands equally after contact with either colonized/infected patients or contaminated surfaces only [41]. However, the importance of contaminated hospital environment and its sanitation are still debated worldwide [42]. The percentage of hospital surfaces contaminated with MRSA ranges from 1– 27% [29]. The people are the main source of *S. aureus.* Sixty five percent of nurses who performed patient care activities on patients with MRSA in a wound or urine contaminated their nursing uniforms or gowns [29]. High-touch surfaces where MRSA has been found include: rails, bedside tables, dressers, blood pressure cuffs, TV remote controls, IV pumps, toilet seats and rails and door handles [45].

Biofilms are formed when bacteria adhere to stationary surfaces and self-produce a matrix of extracellular polymeric substance (EPS) that become resistant to antimicrobial agents [46]. Disinfectants can only kill bacteria in the top layer of biofilms, with little or no effect on bacteria deeper in microcolony [47]. Although studies of *Staphylococcal* biofilms have typically focused on wet sites and medical devices, recent studies have found dry surface bacteria to be almost ubiquitous on hospital surfaces [48]. It also highlights the role of biofilms as a persistent environmental source of pathogens that can be transferred from hands to bacterial carriers [49]. Biofilms can facilitate Horizontal gene transfer (HGT), which is a process by which bacteria can exchange genetic material with other bacteria, regardless of their taxonomic affiliation [50]. HGT can facilitate the spread of antibiotic resistance genes (ARGs) among different bacterial species, leading to the emergence and dissemination of multidrug-resistant (MDR) pathogens, in hospital environments, where antibiotics are frequently used and diverse bacterial populations coexist. HGT can pose a serious threat to public health and patient safety[51].

Chain of contact transmission:

In addition, human-to-human transmission, there is growing evidence that the hospital environment is another important transmission hub, harbouring opportunistic antibiotic-resistant pathogens that contribute to HAIs, and should not be ignored [52], [53]. Surfaces can be classified as either hard surfaces (e.g., window sills, workstations, floors and ceilings, etc.) or soft surfaces (e.g., bed linen, upholstery, apparel, privacy curtains, etc.), several studies have shown that these surfaces are constantly touched by medical staff during patient care and thus represent potential reservoirs for microorganisms and spores [54]–[56]. As shown in figure (1).



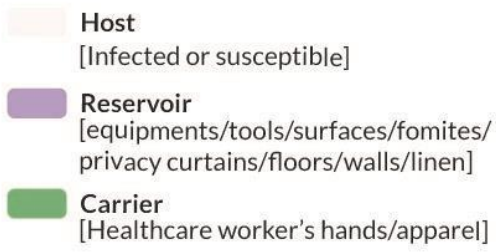


Fig1: Chain of contact transmission [55].

Environmental conditions:

In general, environmental factors such as relative humidity, temperature, ventilation, air change rate, and pressure differences between adjacent rooms have been found to affect bacterial growth and transmission [38], [57], [58]. The CDC environmental Infection Control Guidelines and the healthcare Infection control Practices advisory committee (HICPAC) recommended a temperature of 20-25°C, a humidity of less than 68% and 6-15 air changes per hour (ACH) is recommended. Figure 2 shows the range of the recommended environmental conditions **[59].**

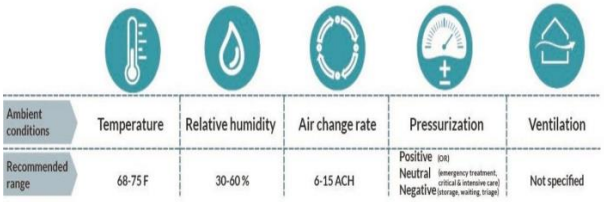


Fig2: recommended range of environmental conditions.

In a study by Lopez et al., 2013 [57], fomite-to-finger transfer efficiency was determined under low and high relative humidity conditions, and *S. aureus* showed different responses to different environmental conditions**. Table 1 summarizes the differences in the behavior of *Staphylococci* on some surfaces relative to temperature and humidity**

Table 1: *Staphylococci* behavior on some surfaces relative to temperature and humidity:

Surface finish/material	Environmental conditions	Impact on pathogen retention, survival, and transmission
Glass	**Low humidity**	**High transfer of S. aureus**
Laminate	**High humidity**	**High transfer of S. aureus**
Copper	**High humidity (>90% RH) and typical temperature (20°C)**	**Less contamination compared with silver ion materials**

Cleaning environmental surfaces:

The benefits of cleaning contaminated surfaces in hospitals can prevent infections and has been known for over 150 years [60]. Since then, several studies have demonstrated the prevalence of nosocomial MRSA and the importance of hospital cleanliness in reducing MRSA-contamination of hospital surfaces and MRSA-outbreaks **[61], [62].**

The choice of strategies for cleaning environmental surfaces should be determined by factors such as the type of items to be cleaned [63]. Dancer at., al. in 2009 [64] showed a higher rate of MRSA acquisitions when routine cleaning was performed, while during the period of enhanced cleaning there was a decrease of more than half of the cases**.** Datta et al. [63] emphasized the need for enhanced cleaning in 2011 when they discussed the acquisition of MRSA in rooms previously occupied by patients who had these bacteria colonized, the acquisition of MRSA decreased from 3% to 1.5%, demonstrating that enhanced cleaning may reduce MRSA transmission.

Finally, two recent works focused their attention on the effectiveness of an enhanced cleaning using two innovative sanitation techniques for MRSA environmental contamination, the first study used a pulsed xenon UV device that included patient screening, environmental sampling, hand hygiene and laboratory techniques. This approach reduced hospital-acquired MRSA by 56% after 6 months, the second study was longer than the first and evaluated the effectiveness of hydrogen peroxide (HP) decontamination in combination with patient screening for MRSA over 6 years [65]**.**

In addition, studies suggest that some lesser known high touch pathogen reservoirs (e.g., privacy curtains) are not cleaned or disinfected unless they are visibly soiled **[66]–[68].**

Cleanliness of high-touch surfaces in healthcare facilities is usually assessed by visual inspection, however using microbiological screenings (e.g., aerobic colony count) surfaces that appeared clean did not meet reference requirements **[69]**.

Watson et al. [70] evaluated the impact of implementing a hospital patient and environmental cleanliness protocol on the incidence of MRSA infections and the cost-effectiveness of an intervention consisting of enhanced environmental cleaning of high touch surfaces, washing patients with benzalkonium chloride and isolating patients with active infection MRSA rates fell from 3.04 to 0.11/1,000.

Concluding remarks

The role of the hospital environment in the transmission of HAIs is still debated worldwide. Scientific evidence supports the hypothesis that hospitals can act as an important reservoir of many nosocomial pathogens in several environments, such as surfaces, medical equipment, and water systems. Incorrect behavior of healthcare workers can determine the cross-transmission of pathogens by environment-patients and patient-to-patient routes. An adequate and enhanced cleaning of the hospital environment, antimicrobial stewardship, and an educational campaign about correct behaviors to adopt by healthcare workers can represent possible solutions to HAIs, particularly antibiotic-resistant strains, which are a major cause of hospital- and community-acquired infections. These bacteria are ubiquitous and widely spread in the environment; they have a remarkable ability to survive well under diverse environmental conditions. They are able to persist for long periods in various habitats; in addition, they may act as reservoirs for the dissemination of resistance genes to other species because of their ability to survive and acquire resistance genes in the environment.

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