

Role of *Staphylococcus aureus* in skin and soft tissue infection

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ABSTRACT

Staphylococcus aureus is a Gram-positive, facultative anaerobic bacteria that penetrates human skin and soft tissues. Skin and soft tissue infections (SSTI) triggered by *Staphylococcus aureus* are growing increasingly prevalent globally, in hospitals moreover, the community. Methicillin-resistant *Staphylococcus aureus* (MRSA) infections are widely reported in hospital and community contexts, and they might also consist of additional pathogenic bacteria and fungi. *S. aureus* generates almost one-third of severe bacterial skin and tissue infections, especially methicillin-resistant *Staphylococcus aureus* (MRSA). Its ability to remain in the skin, either commensally or during an infectious phase, is greatly affected by its cellular structural makeup and population diversity. It causes tissue infection when the skin or mucosal membranes are compromised, resulting in numerous illnesses such as boils, tumors, and cysts. SSTI can range from minor epidermal infections to life-threatening necrotizing fasciitis. *S. aureus* was sensitive to most of antibiotics, including Tetracycline, penicillin, ciprofloxacin, doxycycline, and azithromycin, Clindamycin, and chloramphenicol. This study focuses on the mechanism of this bacterium in the context of infection and available treatment options.

Keywords: *Staphylococcus aureus*, skin and soft tissue infections (SSTI), Methicillin-resistant *Staphylococcus aureus* (MRSA), antibiotics, mechanism, treatment options

INTRODUCTION

Among the many dangerous enemies in the field of infectious diseases is *Staphylococcus aureus*, that frequently lives on healthy human skin, noses, and mucous membranes. This resilient organism has the alarming ability to develop antimicrobial resistance, either through spontaneous mutations or the acquisition of genes used by other bacteria to develop resistance, thereby becoming a leading source of human infections worldwide (Linz et al. 2023). Renowned for its adaptability, *S. aureus* invades human skin as part of the commensal flora, often resulting in various infections. *S. aureus* is The most prevalent bacterial infection linked to Skin and Soft Tissue Infections (Mariani et al. 2023). SSTIs are the most prevalent infectious condition requiring medical treatment. Folliculitis is a minor variety, but necrotizing fasciitis is life-threatening. *S. aureus* predominantly manifests in SSTIs such as impetigo, wounds, furuncles, burns, and abscesses, as well as respiratory and urinary tract infections (Mahakalkar et al. 2020). Healthy skin is dry, has a low pH, constantly sheds its upper layer, and produces antimicrobial peptides, creating a hostile environment for bacteria. However, *S. aureus* can overcome these defences due to its cellular structure and population heterogeneity, allowing it to colonize the skin. It adapts to stressors present in conditions like atopic dermatitis and chronic wounds in diabetes patients (Gehrke et al. 2023). *S. aureus* causes skin infections through the deployment of various virulence factors. These include cytolytic proteins, super-antigenic factors, cell wall-anchored proteins, and molecules designed for immune evasion. The immune response to SSTIs begins with the action of keratinocytes and neutrophils as initial responders, which are later supported by dendritic cells and T-lymphocytes throughout the entire infection (Linz et al. 2023). *S. aureus* can cause infections anywhere on the body with pilosebaceous units. However, it is most commonly isolated in cases of hair loss, which typically

affects the face. Folliculitis, the inflammation of a hair follicle, usually presents as clusters of red papules less than 5 mm in diameter. The risk factors for SSTIs, particularly those strains sensitive to methicillin, are well-documented. These include various co-morbidities such as diabetes mellitus, Peripheral vascular disease, renal disease, cardiovascular disease, chronic wounds, immunosuppression, intravenous drug use, and the existence of abscesses. Children are at a higher danger of creating skin infections if they have eczema, chronic health conditions, nail-biting habits, or should they be Black. Other danger factors include possessing a household member with a skin infection within the past year or being colonized with methicillin-resistant *Staphylococcus aureus* (MRSA) (Linz et al. 2023).

MATERIALS AND METHODS

Searching PubMed, PubMed Central, Google, and published research and review articles worldwide on the environmental pollutants generated by the leather industries and the microbial bioremediation technique to eliminate the pollutants for a cleaner world is how the relevant material for this review paper was discovered. Only published data was taken into account; ambiguous exposure statements were not. A component of these inclusion criteria is information gathered from reliable publications on the topic. The only language included in the study was English.

Virulence factors

Many virulence factors, such as cytolytic proteins, super antigenic factors, molecules useful for immune evasion, and cell wall-anchored proteins, are produced by the bacterium *S. aureus* and are believed to be significant for skin infections. Protein A and clumping factor are examples of adhesins that help cells and tissues adhere to one another. Alpha-toxin and Panton-Valentine Leukocidin (PVL) are two examples of toxins that can harm tissue and induce necrosis. Enzymes capable of breaking down host tissues and aid invasion include lipases and proteases (Kobayashi et al. 2015).

Pathogenesis

Colonization

The skin and mucous membranes are the first places where this opportunistic infection settles. In places like the skin or nose, where the bacteria can find the perfect conditions to flourish, this colonization frequently takes place. Surface proteins that aid in adhesion to host tissues, such as clumping factors and fibronectin-binding proteins, are produced as the main mechanism of colonization. The bacteria are able to take root because these proteins bind them to the skin and mucosal surfaces. Colonization typically has no symptoms, but if the skin barrier is weakened, it can lead to infection. A number of variables, including skin conditions, immune system function, and personal hygiene, might affect how much colonization occurs. One of the main risk factors for future infections is nasal carriage of *S. aureus*.

Invasion

The invasion phase begins when *S. aureus* breaches the skin barrier, typically through minor trauma, such as cuts, abrasions, or insect bites. The bacteria exploit these breaches to penetrate deeper into the skin and underlying tissues. Several virulence factors facilitate this invasion process:

Enzymes: *S. aureus* secretes a variety of enzymes, including proteases, lipases, and hyaluronidases, that degrade the structural components of the skin. This enzymatic activity breaks down proteins, lipids, and hyaluronic acid, creating pathways for the bacteria to invade.

Toxins: The production of cytolytic toxins, such as alpha-toxin and Panton-Valentine Leukocidin (PVL), helps in lysing host cells, leading to harm to tissue, and facilitating bacterial spread. Alpha-toxin forms pores in the membranes of host cells, leading to cell lysis and tissue necrosis.

Adhesins: The existence of adhesins, which are proteins found on the surface and bind to host extracellular matrix components, allows the bacteria to firmly attach to and invade host tissues.

During this phase, the host's innate immune response is activated. Neutrophils, the first responders, attempt to contain the infection through phagocytosis and the release of antimicrobial substances. However, *S. aureus* has evolved mechanisms to evade these defenses, including the production of protein A, which binds to the Fc region of antibodies, preventing opsonization and phagocytosis.

Proliferation

Once *S. aureus* has successfully invaded the tissues, it begins to proliferate and spread, causing significant tissue damage and inflammation. The proliferation phase is characterized by the rapid multiplication of bacteria and the dissemination of the infection to surrounding tissues. Several factors contribute to this process:

Iron Acquisition: *S. aureus* requires iron for growth and survival. It produces siderophores, which are small, high-affinity iron-chelating compounds that scavenge iron from host proteins. This ensures a steady supply of this essential nutrient.

Biofilm Formation: Biofilms can arise from *S. aureus*, which are structured groups of microorganisms contained within a self-produced extracellular matrix. Biofilms provide a protective environment that enhances bacterial survival and resistance to host immune responses and antibiotics (Gehrke et al. 2023).

Immune Evasion: *S. aureus* employs several strategies to evade the host's immune system. It produces surface polysaccharides that inhibit phagocytosis and secretes factors that inhibit complement activation. Additionally, the bacterium may alter the immunological responses of the host by releasing proteins that obstruct neutrophil recruitment and function.

The proliferation of *S. aureus* brings about the release of additional virulence factors, further exacerbating tissue damage and inflammation. The host's immune system continues to respond, with additional immune cells, such as macrophages, dendritic cells, and T cells, being recruited

toward the infection location. Despite these efforts, *S. aureus* can persist and establish chronic infections, leading to abscess formation and other complications.

Treatment options

Skin and soft tissue infections (SSTIs) cover a variety of illnesses, from simple superficial infections to potentially fatal disorders like necrotizing fasciitis. SSTI treatment is determined by the kind of infection, causative organisms, disease severity, and patient-specific factors such as comorbidities and allergies.

Oral therapy: It is typically used for *S. aureus* SSTIs, with parenteral therapy reserved for severe cases. Treatment options include cephalosporins and penicillin agents like oxacillin for MSSA and vancomycin for MRSA (Linz et al. 2023).

Empirical therapy: It begins based on the most likely infections and local antimicrobial susceptibility patterns. Non-purulent cellulitis (lack of purulent material) is typically caused by beta-hemolytic *Streptococcus sp.* Mild instances is possible to cure using oral antibiotics such cephalexin (500 mg every 6 hours) and dicloxacillin (500 mg every 6 hours). Clindamycin (300 mg every 8 hours) is advised in situations of severe penicillin allergy. Vancomycin (10-15 mg/kg every 12 hours) may be used for severe infections or those that do not respond to early treatment.

Purulent Infections: *Staphylococcus aureus*, including methicillin-resistant *Staphylococcus aureus* (MRSA), is frequently involved in purulent SSTIs, such as abscess and furuncles. The foundation of abscess treatment is drainage and incision (I&D)². Antibiotics that target MRSA, such as clindamycin, doxycycline, or trimethoprim-sulfamethoxazole, are used empirically to treat cellulitis with purulence.

Treatment options for impetigo, which is caused by *Staphylococcus aureus* and *Streptococcus pyogenes*, include topical mupirocin ointment for mild cases and oral antibiotics like cephalexin for more severe ones. *Staphylococcus aureus* is usually the cause of folliculitis, which is treatable with topical

antibiotics and warm cloths. Necrotizing fasciitis: This serious infection necessitates beta-lactams and vancomycin, among other broad-spectrum antibiotics, as well as rigorous surgical debridement (Stevens et al. 2015).

Adjunctive therapies: In the treatment of SSTIs, adjunctive therapies—like wound care and supportive measures—are essential. Proper wound care, which includes washing and changing dressings, encourages healing and helps avoid subsequent infections (Marcelin et al. 2018).

CONCLUSION

S. aureus is the predominant pathogen causing skin and soft tissue infections (SSTIs). While hospitalization rates for *S. aureus* SSTIs are declining in the U.S., these infections remain a significant healthcare challenge, leading to considerable morbidity and mortality. In 2019, *S. aureus* was the leading bacterial cause of death in 135 countries, contributing to over a million deaths. Most *S. aureus* SSTIs are manageable with oral antibiotics, but they can escalate into severe infections requiring intravenous therapy. With the rise of antimicrobial-resistant strains, experimental treatments like bacteriophage therapy are being explored. MRSA alone was in charge of over 100,000 deaths globally in 2019.

Additional investigation is required to understand host factors and pathways that influence responses to *S. aureus* infections, genetic susceptibility, and virulence factors. New therapeutics targeting bacterial processes like biofilm formation are promising. Challenges in vaccine development, such as the immune-modulating properties of protein A, also need to be addressed. In summary, *S. aureus* is highlighting the need for ongoing research and innovative treatment strategies.

Conflict of Interest

There is no conflict of interest related to the study.

Author contributions

Acquisition and interpretation of data is done by Prakriti Patra. Conception, design and revising of the article are done by Rupesh Dutta Banik.

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