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BIOFILMS: MICROBIAL COMMUNITIES AND THEIR CRUCIAL IMPACT ON HEALTHCARE

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INTRODUCTION

Biofilms, structured microbial communities, play vital roles in diverse ecosystems. A biofilm is a cluster of microorganisms living together within a self- produced protective layer. The biofilm formation process involves sequential stages: 1) Initial attachment, where bacteria adhere transiently to surfaces; 2) Adhesion and aggregation, where adhesins and EPS solidify attachment; 3) Microcolony formation, triggering bacterial multiplication and cooperation; 4) Maturation, with EPS release and gene expression; and 5) Dispersion, allowing bacteria to spread (1–3). These stages impact biofilm stability, microbial interactions, and medical implications, providing insights for control and prevention.

Bacterial biofilms operate as microbial societies where communication is crucial. Quorum Sensing (QS), a cell-cell communication system, extends beyond cell density coordinating roles like cell maintenance, horizontal gene transfer, host- pathogen interactions, and behavior modulation (2). Notably, there are three main QS systems: acyl-homoserine lactone (AHL) in Gram-negative, autoinducing peptide (AIP) in Gram-positive bacteria, and autoinducer-2 (AI-2) in both Gram-negative and Gram-positive bacteria (3). The QS system is a key focus for treating biofilm-related infections. Agents like QS inhibitors (QSIs) and quorum quenching (QQ) enzymes have been developed to control bacterial biofilm formation by targeting various components of the QS signaling pathway (4).

Biofilms have become a subject of extensive research due to their widespread influence across various fields. Biofilms impact healthcare, particularly with medical devices like catheters and prosthetics susceptible to biofilm formation. Urinary catheters, central venous catheters, indwelling stents, prosthetic joints, pacemakers, contact lenses, peritoneal dialysis catheters, and intrauterine devices are medical devices that are susceptible to biofilm formation (1,5). Non-device-related bacterial biofilm infections encompass a range of conditions, from dental plaque and urinary tract infections to cystic fibrosis, otitis media, infective endocarditis, tonsillitis, necrotizing fasciitis, osteomyelitis, and chronic inflammatory diseases, illustrating the diverse impact on body systems.5,6 Biofilm's adaptive strategies enable them to evade immune responses, promoting chronic infections (7).

Managing biofilm challenges in healthcare is crucial for precise infection diagnosis and effective treatment. Failure to combat biofilms adequately may lead to an increase in the frequency and severity of infections, resulting in elevated infection-related mortality and morbidity (1). The widespread use of antibiotics has led to antibiotic-resistant bacteria. A comprehensive understanding of biofilm formation and effective strategies, including surface design and antimicrobial coatings, is vital (1). Recent biofilm inhibition strategies, including antimicrobial peptides and quorum sensing blockage, present promising avenues to combat biofilm-related infections by disrupting bacterial communication, rendering pathogens susceptible to immune responses and antibiotics (2).

In healthcare, according to the US National Institutes of Health, biofilms contribute to over 80% of microbial infections, imposing a substantial economic burden (8). The economic impact is significant, with chronic wounds alone costing $7800 billion in global healthcare (8). Catheter-associated infections, prosthetic joint complications, personal care, and oral care further escalate economic impacts, highlighting the broad effects of biofilm-related complications on healthcare costs (8).

Optimal health demands attention to effective biofilm management. Understanding the molecular basis of biofilm formation is essential for developing targeted strategies against biofilm-associated issues. These complex challenges underscore the need for innovative approaches and detailed molecular insights to enhance patient outcomes and combat biofilm-related infections effectively.

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