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Commentary

Bacterial Biofilms: The Hidden Threat in Chronic Infections

Daryl Schroth*

Department of Biochemistry and Medical Genetics, University of Manitoba, Winnipeg, MB, Canada

DESCRIPTION

Bacterial biofilms represent a complex, resilient form of microbial organization that poses a significant challenge in the treatment of chronic infections. Unlike free-floating, planktonic bacteria, biofilms consist of bacteria embedded in a self-produced matrix of Extracellular Polymeric Substances (EPS), adhering to surfaces. This matrix shields the bacteria from external threats, including antibiotics and the host immune system, making biofilms a key factor in chronic, recurring infections. Understanding bacterial biofilms and developing effective treatments is critical to addressing a wide range of persistent infections that pose serious risks to public health.

What are bacterial biofilms?

A biofilm is a structured community of bacterial cells enclosed in a self-generated polymeric matrix and attached to a surface. This surface can be living, such as tissue or organs in the human body, or non-living, such as medical devices, water pipes, or industrial equipment. Biofilms can form in virtually any environment, from natural settings like riverbeds and soil to artificial environments such as hospital settings, where they often form on medical devices like catheters, prosthetics and pacemakers.

The formation of a biofilm

Initial attachment: Planktonic (free-floating) bacteria attach to a surface using various adhesion molecules.

Microcolony formation: After attachment, the bacteria begin to proliferate and form small colonies.

Maturation: As the biofilm grows, bacteria secrete the Extracellular Polymeric Substance (EPS), a slimy, protective matrix made of polysaccharides, proteins and DNA. This matrix helps bacteria stick together and to the surface, while protecting them from environmental stresses.

Detachment: In the final stage, portions of the biofilm may break off, releasing planktonic bacteria that can spread to other parts of the body or environment and start new biofilms.

Biofilms and chronic infections

Biofilms are implicated in a variety of chronic infections, many of which are well-knowingly difficult to eradicate. Some of the most common chronic infections associated with biofilms include:

Chronic wounds: Biofilms are a major factor in the persistence of chronic wounds, such as diabetic foot ulcers or bedsores. In these cases, biofilms form on the surface of the wound, preventing healing and making the infection resistant to antibiotics and other treatments. The bacteria in biofilms can communicate with each other, coordinating their defense mechanisms and evading both antibiotics and the immune system.

Cystic fibrosis: In patients with cystic fibrosis, biofilms form in the lungs, particularly from bacteria like *Pseudomonas aeruginosa*. These biofilms cause recurrent lung infections, leading to chronic inflammation and progressive lung damage. The thick mucus in cystic fibrosis patients creates an ideal environment for biofilm formation, contributing to the difficulty in managing these infections.

Chronic sinusitis: Biofilm formation in the sinuses is a common cause of chronic sinus infections. Bacteria like *Staphylococcus aureus* or *Haemophilus influenza* form biofilms in the sinuses, making the infection resistant to antibiotics. This leads to recurring symptoms, despite repeated courses of medication.

Urinary Tract Infections (UTIs): Biofilms are a major factor in chronic and recurrent urinary tract infections, particularly in patients with indwelling catheters. Bacteria such as *Escherichia coli* can form biofilms on the surface of the catheter, leading to persistent infections that are difficult to treat and often recur after antibiotics are discontinued.

Correspondence to: Daryl Schroth, Department of Biochemistry and Medical Genetics, University of Manitoba, Winnipeg, MB, Canada, E-mail: daryl.s@gmail.com

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Dental plaque and periodontitis: The formation of biofilms on teeth, commonly known as dental plaque, can lead to tooth decay, gingivitis and periodontitis. The biofilm shields bacteria from mechanical removal (such as brushing) and chemical treatments, contributing to the progression of periodontal disease.

Mechanisms of biofilm resistance

The resistance of biofilms to antibiotics and immune responses is multifaceted:

Physical barrier: The EPS matrix physically blocks the penetration of antibiotics and immune cells, reducing the ability of treatments to reach the bacteria inside.

Altered microenvironment: Inside the biofilm, bacteria exist in different metabolic states. Some bacteria are in a slow-growing or dormant state, making them less susceptible to antibiotics that target actively dividing cells. This creates a "persister" population within the biofilm that can survive antibiotic treatment and later regenerate the infection.

Gene transfer and mutation: Bacteria in biofilms can exchange genetic material more easily, leading to the spread of resistance genes. The biofilm environment can also promote mutations that further enhance resistance to antibiotics.

Emerging solutions to combat biofilms

Given the challenge that biofilms present, novel strategies are urgently needed to combat them. Some of the most potential approaches include:

Anti-biofilm agents: Researchers are developing agents that target the biofilm matrix itself, disrupting its structure and allowing antibiotics to penetrate more effectively. These agents include enzymes like DNase, which breaks down the extracellular DNA in the matrix and molecules that inhibit the formation of the EPS matrix.

Quorum sensing inhibitors: Quorum sensing is a communication system used by bacteria to coordinate biofilm formation. By disrupting quorum sensing, it is possible to prevent bacteria from forming biofilms or make existing biofilms more susceptible to antibiotics.

Nanotechnology: Nanoparticles, such as silver or gold nanoparticles, are being explored for their ability to penetrate biofilms and deliver antibiotics directly to the bacteria. These nanoparticles can also have antimicrobial properties of their own, helping to kill bacteria more effectively.

Immune modulation: Enhancing the body's immune response to biofilms is another potential strategy. This involves using immune-modulating drugs or therapies to help the immune system better recognize and destroy biofilm-associated bacteria.

CONCLUSION

Bacterial biofilms represent a hidden yet impressive threat in chronic infections. Their ability to resist antibiotics and evade the immune system makes them a significant challenge in modern medicine. However, with ongoing research and the development of innovative treatments, there is hope for more effective solutions to manage and eradicate biofilm-associated infections. As our understanding of biofilms deepens, it will become increasingly possible to combat this hidden threat and improve outcomes for patients with chronic infections.