MORPHOLOGICAL AND BIOCHEMICAL CHARACTERISTICS OF BIOFILM-FORMING BACTERIA IN SURGICAL DRAINS

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The use of drains in surgical practice is a long-established and time-tested approach, yet it still retains certain “delicate aspects” that require attention. Drains serve to evacuate exudate from wounds, remove purulent contents, and reduce pressure. However, the rapid and persistent colonization of drain surfaces by microorganisms represents one of the most common and challenging complications encountered in surgical practice.

According to modern epidemiological data, the frequency of biofilm formation on surgical drains ranges from 65% to 85%, and in more than 70% of drain-associated infections, the presence of a biofilm has been confirmed. Bacteria that form biofilms may be 50 to 1000 times more resistant to antibiotics compared to planktonic microorganisms. Therefore, studying the morphological structure and biochemical activity of drain-associated biofilms has significant clinical importance.

The analytical foundation of this work is based on several prospective and observational studies, review articles, and laboratory investigations. Microscopic and culture analyses performed on samples collected from surgical drains demonstrated that biofilm elements form rapidly and persistently on drain surfaces. Both multicenter and single-center observational studies recorded a high proportion of surgical site infections associated with biofilm formation; in the general scientific literature, biofilm-forming microorganisms are responsible for approximately three-quarters of all surgical site infections.

Scanning electron microscopy (SEM) of drain tips and plastic drain surfaces showed that, even within the first 24 hours after surgery, bacterial adhesion and the development of early biofilm structures can be detected. Similar findings were observed in large orthopedic prosthesis studies. In many cases, however, this initial layer does not progress to a mature (fully developed) biofilm. This indicates that short-term drains may serve as substrates for early biofilm formation, yet they do not always correlate with delayed or clinically significant infections.

Microbiological cultures and molecular identification revealed that the most common biofilm-forming organisms found on drains include Staphylococcus aureus, coagulase-negative staphylococci, Pseudomonas aeruginosa, various Enterobacteriaceae, and Enterococcus species. Experimental studies show that bacteria in biofilm form exhibit significantly higher antibiotic tolerance compared to their planktonic counterparts; according to published data,

biofilm-embedded cells may demonstrate 10^2–10^3-fold higher tolerance to antimicrobial agents, which severely reduces the effectiveness of clinical therapy.

Biochemical analyses identified extracellular polysaccharides, proteins, extracellular DNA, and lipids as the primary components of the biofilm matrix. This matrix protects bacteria from antimicrobial substances, phagocytosis, and mechanical forces. Enzymatic activities within the matrix (including β-lactamases, proteases, and nucleases) along with regulatory signaling molecules such as c-di-GMP and quorum sensing components support biofilm stability and antibiotic tolerance. These molecular mechanisms strengthen colonization on drain surfaces.

Clinical observations demonstrated that the type of drain (open versus vacuum), duration of drain placement, and degree of surgical field contamination all increase the likelihood of biofilm formation. Several studies identified a statistically significant association between the presence of drains and the risk of surgical site infections. However, it was also noted that a positive biofilm finding on the drain tip does not always lead to deep purulent complications such as prosthetic joint infection, which suggests that additional factors (aseptic technique, patient immune status, contamination level) also play essential roles.

The clinical implications of biofilm formation should be viewed from two major perspectives. First, biofilms exhibit strong resistance to antibiotic therapy, making antibiotic treatment alone insufficient. Second, the presence of biofilm in the drain does not always correlate with a direct cause-and-effect relationship with surgical infections; several studies reported that even with visible biofilm formation on the drain tip, long-term prosthetic infections did not occur. This underscores the multifactorial nature of infection risk.

Practical recommendations are based on empirical evidence from scientific literature. It is advisable to reassess the necessity of drain placement and remove drains as early as possible, especially in cases where monitoring is difficult or the patient's infection risk is high. Laboratory and clinical studies focusing on antibiofilm coating technologies, antiseptic irrigation protocols, and drain material modifications are promising approaches to mitigate biofilm-related complications. New therapeutic strategies such as bioelectric methods, nanomaterial coatings, and quorum-sensing inhibitors show experimental efficacy in weakening or eliminating biofilms, though large-scale clinical validation is still required.

Limitations and future directions should also be noted. Heterogeneity in study designs, sampling and analytical methods, drain types, and patient populations complicates the generalization of results. Future multi-center studies with standardized methodology—stratifying drain types, duration of placement, and patient risk factors—are needed. Furthermore, the development of molecular biomarkers and real-time monitoring systems (such as biofilm-specific markers on the drain surface) may be valuable tools for early detection and targeted prevention in clinical practice.

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