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Review article

Effect of nanomaterials in catheter related nosocomial infection

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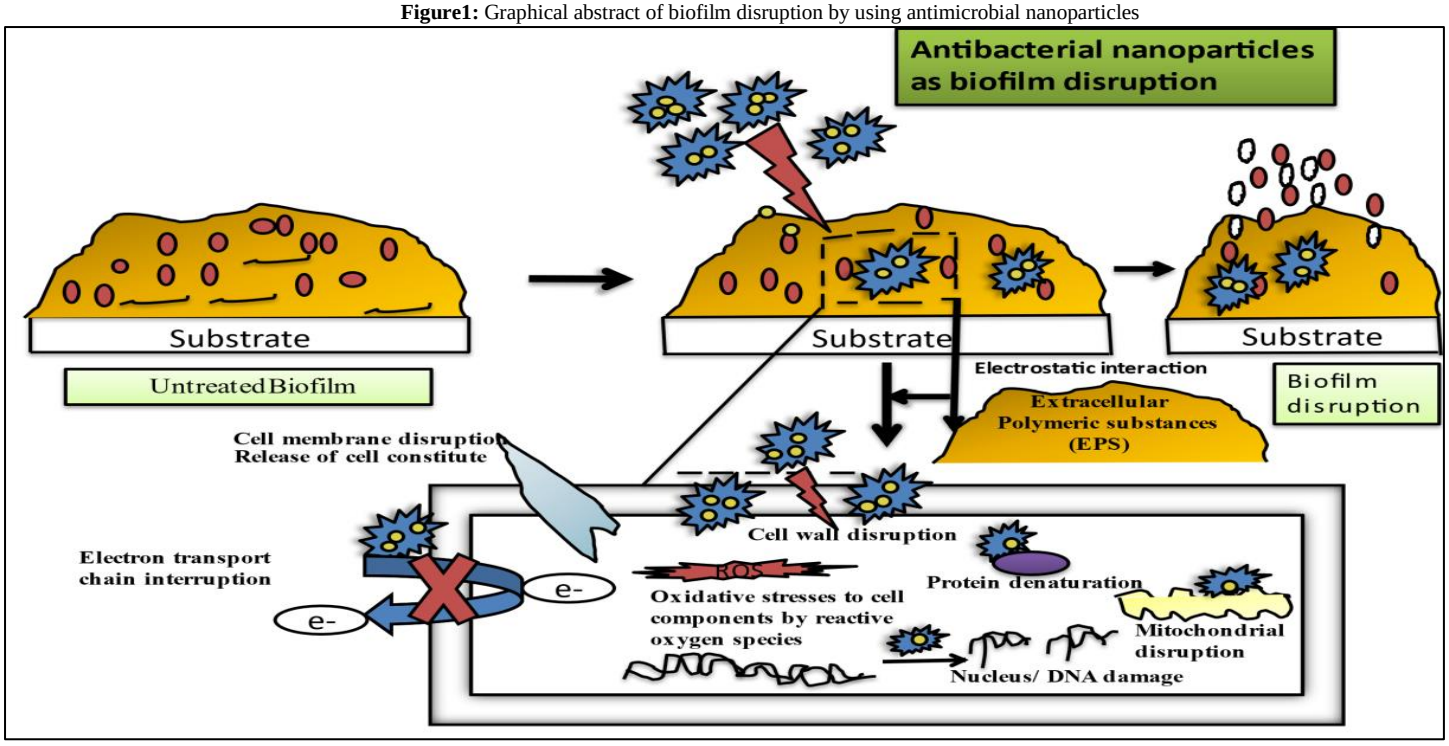
ABSTRACT

In the current healthcare environment, nosocomial infection is regarded as one of the most life-threatening infections. Hospitalized patients are exposed to contaminants from a range of sources, including medical staff and other sick people. Bacteria associated biofilm infection spread in central line associated blood infections, catheter-associated urinary tract infection, surgical site infection and ventilator-associated respiratory system. According to WHO reports, nearly 15% of all hospitalized patients suffer from this infection. Patients with indwelling urinary catheters have a higher risk of developing urinary tract infections because biofilm formation bacteria can enter the urinary system directly. Metal based nanoparticles is the most advantageous in prevention of biofilm disruption rather than conventional antibiotics. The creation of engineering tailored nanoparticles may signal a new era in the efficient treatment of nosocomial infection caused by the growth of biofilm over indwelling catheters. Nosocomial infections, Healthcare associated infection, Catheter associated infections, engineering tailored nanoparticles, Biofilm Surface.

Figure1: Graphical abstract of biofilm disruption by using antimicrobial nanoparticles



Keywords: Nosocomial infections, Healthcare associated infection, Catheter associated infections, Eng. tailored nanoparticles, Biofilm Surface

INTRODUCTION

Nosocomial infections are secondary infections that affect most of the hospitalized patients and are mainly caused by various pathogens. It is seriously affected by Hospital patients and among every 100 hospitalized patients, 10 are affected by nosocomial infections globally. These infections mainly occur due to the use of implantable medical devices such as intravascular and urinary catheters. 7 million intravascular catheters are used each year around the world, and the majority of them are linked to the development of bloodstream infections. The majority of hospitalized patient infections worldwide (up to 80%) are caused by indwelling urinary catheters, which also result in nosocomial infections [1]. The development of bacterial biofilms on the surface of implanted medical devices is the primary cause of these illnesses.

The best strategy to avoid infections linked to catheter use is to implant catheters in a completely sterile environment. The creation of the perfect catheter that can prevent biofilm formation is still an unmet medical need, despite the widespread reporting of the utilization of many antiseptic and sterile catheters in several literatures. The optimal antimicrobial catheter should remain active while in contact with body fluids and should do so throughout the duration of catheterization. Along with having a broad antibacterial spectrum, the antimicrobial agent should also inhibit biofilm formation and not encourage the evolution of resistance [2].

Biofilms:

Any collection of microorganisms in which several microbial cell types adhere to one another after attaching to a surface is referred to as a biofilm [3]. Bacterial cells communicate with their surroundings through the use of organic polymers having microbial made up of DNA and protein, which mediate their stabilization through cell-to-cell and cell-to-surface contact and enable biofilm development. Biofilms are made up mostly of one or more bacterial species that are embedded in bacterial cells. Among other things such as proteins, enzymes, DNA, and RNA, Water is the primary component of bacterial cells and is in charge of the movement of nutrients inside the biofilm. The major components of a bacterial biofilm are as follows [4]. Microbial cells are 2 to 5%, DNA and RNA is Less than 1 to 2%, Polysaccharides is 1 to 2%, Proteins Less than 1 to 2% and water up to 97%.

Biofilms Formation

The major steps of biofilm formation are as follows

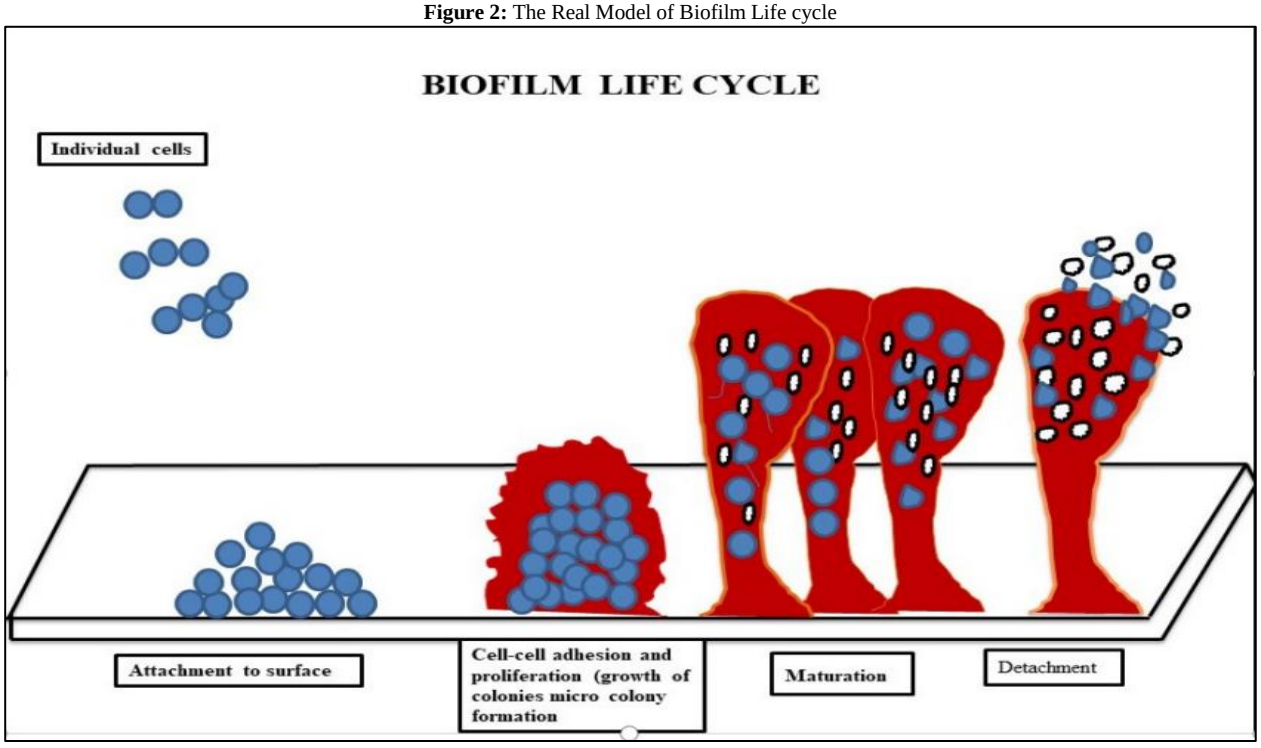
a) Attachment to surface: The tendency of bacterial cells to create a reversible attachment upon contact with any surface may be shown. Bacteria that are algae can stick to both living and non-living surfaces.

b) Micro colony formation: After attaching to the surface, bacterial genetic modifications cause the start of extracellular substance secretion, and then cell division inside extracellular substance results in the creation of microcolonies.

c) Formation of 3D structure and maturation of biofilms: Water channels are created as a result of matrix development, serving as a circulatory system for the transfer of nutrients.

d) Detachment of biofilms: The key factor preventing extracellular material generation from occurring during biofilm dispersion, which happens after the maturation stage. Dispersion of the biofilm can also be caused by changes in the availability of nutrients and variations in oxygen levels.

Figure 2: The Real Model of Biofilm Life cycle



Some important properties of biofilms

Biofilms are very adaptable to environmental changes. Biofilms are able to move across a surface. Quorum sensing allows bacteria inside a biofilm to interact with one another. Biofilms can persist longer than planktonic germs because they are very resistant to antimicrobial treatments. They have the ability to withstand phagocytosis and other elements of the body's natural defense system. Many antibiotics are unable to penetrate biofilms because of the extracellular material that serves as a physical barrier to them. Numerous antibiotic-neutralizing enzymes, including as beta lactamase and cephalosporin amp C enzymes, are present in them [5].

Biofilm related infections occurs in medical implants:

The usage of implanted medical devices has become widespread among medical professionals as a result of significant improvements in the health care sector. However, using them increases the risk of bacterial infections, which are said to be the leading cause of death and disability [6]. Blood stream infections can result from using different medical implants, and these infections are greatly burdening the healthcare business every year. There have been several reports of biofilms developing on the surface of medical implants. Nosocomial infections caused by biofilms pose a serious health risk and may even necessitate the removal of some vital implants, including pacemakers and prosthetic knee joints.

Biofilms are formed over indwelling catheters

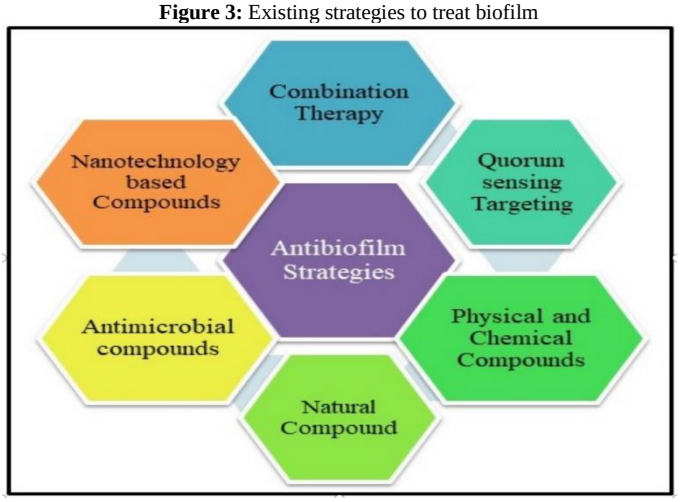
Blood stream and urinary tract infections are brought on by the biofilm growth over central venous and urine catheters. Free-flowing planktonic bacteria readily develops biofilms on catheter surfaces because they lack an innate defense system. Patients with indwelling urinary catheters have a higher risk of developing urinary tract infections because urinary catheters create a direct link between the bladder and the urinary system, allowing bacteria from biofilm to enter the urinary system. Biofilm-forming bacteria can cause serious blood stream infections that can result in sepsis throughout the body. They may also result in the development of kidney stones, pyelonephritis, chronic prostitis, and acute urinary tract infection [7]. The following are some issues in treating biofilms: It is very difficult to treat biofilms with standard antibiotics. Biofilms are capable of transferring antibiotic resistant genes.

Existing strategies to treat biofilm based nosocomial infection: The destruction of biofilms formed over catheters is still an unfulfilled goal for the researchers across the world. The extreme antibiotic resistant property of biofilms makes the task extremely challenging. The various approaches that are currently used to prevent biofilm formation over catheters are as follows:

Systemic antimicrobial therapy

They can be helpful in curing biofilm related infections but the therapy is often limited by high dose usage and extreme antibiotic resistant nature of biofilms.

Figure 3: Existing strategies to treat biofilm



Surface modification and coating of catheters: Smart antibiofilm coatings are being developed to prevent the adherence of planktonic bacteria to the catheter surface. Vancomycin [8], silver [9], furanones [10], and quaternary ammonium compounds [11] are only a few of the coating materials that are frequently employed to cover catheter surfaces to stop bacterial adherence. To stop the growth of biofilm, catheters can be coated with several biodegradable polymers as PLGA, PLA, and PEG [12]. These polymer release antibiotics for a prolonged period of time but fails to provide complete protection due to high antibiotic resistant nature of biofilms. Antiseptic coatings are more effective than antibiotic coatings and help to prevent the formation of biofilms. Photoactive based coatings of anastase titanium dioxide can also resist biofilm formation. However, they require UV radiation for activation which may not be always feasible. Antiadhesion coatings reduce the attachment of planktonic bacteria to the catheter surface. Trimethyl silane nano-coatings are used to coat stainless steel and titanium surfaces to prevent bacterial adhesion [13]. Rough catheter surfaces, polymer brush coatings and organo-selenium coatings can also prevent biofilm formation over catheter surfaces [14]. Silver is one of the most efficient compounds that can prevent biofilm formation and offers some potential advantages including non-toxic nature, excellent tissue compatibility and can cause bacterial cell death by respiratory chain damage. Silver also helps to prevent adhesion of planktonic bacteria to catheter surfaces and several groups of researchers have used silver coatings to prevent biofilm formation over catheters.

The role of nanotechnology in prevention of biofilm formation over catheters

Recent advancement of nanotechnology in medical field for destruction of biofilms formed over catheters. The most emerging domain of biofilm related research and nano materials can ensure effective management of biofilm related infections.

Carbon Nanomaterial's as antibacterial agents

Since carbon is the element that is found in nature in the

greatest amount, researchers studying nanotechnology have recently been interested in carbon-based nanoparticles. Because they are much smaller and have a bigger surface area than other particles, carbon nanoparticles interact with biofilms more effectively. They offer outstanding temperature resistance, strong conductivity of electricity, and superb clarity. They may be created from small quantities of basic components and are cheap to make. Carbon nanoparticles are inherently antimicrobial due to their small size and hydrophilic nature. Negatively charged bacterial cells can be killed by interaction with positively charged carbon nanoparticles with changed surfaces The first four steps in the antimicrobial process are the rupture of the bacterial cell membrane, the production of reactive oxygen species, the penetration of the bacterial cell wall, and the beginning of intracellular antimicrobial effects, including interactions with DNA and proteins. These are the antibacterial properties of carbon-based nanoparticles. Through oxidative stress, carbon-based nanoparticles damage bacterial membranes. Membrane of bacteria are harmed by carbon-based nanomaterials because of an oxidative stress. When bacterial cells congregate with carbon nanomaterials, direct cell-to-carbon nanomaterial contact occurs, which kills bacteria by causing cell death.

Table1: Anti biofilm properties of nanomaterial used in medical field

Nanomaterial	Mechanism of action	Advantages	Medical devices	Reference
Silver	Disruption of Bacterial cell membranes and electron transfer	Silver nanoparticles stopped the growth of the biofilm. It works well against Pseudomonas aeruginosa, which is multidrug resistant.	central venous catheter, urinary catheter	Busscher HJ et.al [20].
Zinc oxide	Damage to the bacterial cell wall and membrane	It works well against a variety of statins and has good antibacterial effectiveness at a cheap cost and low concentration.	Surface treatment for medical equipment	Roger Bayston et.al .[21].
Titanium Dioxide	Damage to the bacterial cell wall and membrane	It is thermal effects of light used in microbial destruction	Implant dentistry and surgical implants	Chen M et.al [22].
Gold	Damage to the bacterial cell wall and membrane causes the bacteria to die by leaking their internal contents.	Adjustable in size and shape, it is also biocompatible and biodegradable.	Implant dentistry devices, pacemakers, and stents	Inglis TJ *et.al.*[23]
Fullerenes	Damage to the bacterial cell wall and membrane	extensively used in sensor applications; great tensile strength; good electrical conductivity; resistance to photodegradation	X-ray, MRI, and drug delivery to the targeted organ	Antoci Jr et.al. [14]
Graphene oxide	DNA damage to bacteria is caused by the graphene oxide nanomaterial used to remove phospholipids from the cell membrane of E. coli bacteria.	strong tensile strength, strong electrical conductivity,	Used as an medical implant	Ma Y et al. [16]
Carbon nanotubes	Damage to the bacterial cell wall and membrane causes the bacteria to die by leaking their internal contents.	used in non-invasive, biosensors for the treatment of many diseases	used in a variety of surgical procedures. employed in biosensors and bioimaging as well	Kostakioti M et al. [17]

Nanocomposites with superior antimicrobial and anti-biofilm characteristics for catheter coating

Catheters with a silver alloy coating mix a hydrogel coating on the latex or silicone surface with a layer of silver alloy made of gold, silver, and palladium [15]. Guo et al., reported that, on polyurethane catheters with equivalent distribution in the inner and outer layer, silver-coated nanoparticles were inhibiting the growth of bacteria. Silver-coated nanoparticles are more effective against Gram-negative bacteria in comparison to gram-positive bacteria [16]. Antibacterial capabilities nanoparticles coated copper have been shown to attach to the DNA-phosphate site, damage bacterial cell walls and membranes, and degradation of DNA, which results in cell death [17]. According to Ritmi et al., Cu and Ag alone or in combination with a polyurethane coating on a catheter surface have antibacterial properties against E. coli. No bacteria were discovered during a two-minute incubation period with the coated catheter surface. Additionally, it shown that the performance of the Cu-Ag coating was superior to coatings consisting of only one metal [18]. According to Shalom et al., Catheters covered with copper oxide nanoparticles doped with zinc ions shown antibacterial and antibiofilm qualities in both lab testing and animal experiments using a rabbit model. Over the course of 24 hours of exposure to flow conditions, it was shown that coated catheters greatly decreased the production of biofilm by different bacteria by over 90% when compared to uncoated catheters [19] ,[20].

Future prospects

Catheter biofilm inhibition by using nanoparticles is new era in medical science. Due to small particles size of nanoparticles can act as a carrier of active ingredients to the site of action. Nanoparticle directly goes through the blood steam and reach to the infection site. Metal based nanoparticles is the most advantageous in prevention of biofilm disruption rather than conventional antibiotics.

CONCLUSION

Future studies on the antibacterial activity of carbon-based nanostructures might be quite fascinating given their properties, big inner volume, and other unique chemical and physical characteristics. Additionally, employing functionalized carbon nanomaterials as delivery methods for typical antibiotics could reduce the accompanying resistance, boost their absorption, and permit tailored administration. Carbon nanoparticles are a great option for preventing

the growth of biofilm on surfaces of indwelling catheters. Due to their hydrophilic nature and surface charge, surface modified carbon nanoparticles made from simple, cost-effective, and environmentally friendly sources can destroy bacterial biofilms. Thus, the creation of intelligently tailored carbon nanoparticles may signal a new era in the efficient treatment of nosocomial infections caused by the growth of biofilm over indwelling catheters.

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CONFLICTS OF INTEREST

I declare that there are no potential conflicts of interest

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