Research Article

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# ANTIBACTERIAL DRUG AND CARRIER LOADED CATHETERS TO RETARD DEVICE ASSOCIATED BACTERIAL INFECTIONS

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**ABSTRACT**

In this research work, the intravascular catheter surface was modified with antibacterial coatings for the prevention of bacterial biofilm formation. Surface was coated with two synergistic drug combinations (Moxifloxacin-Ornidazole) grafted with a biodegradable carrier (DL-lactic acid). The carrier acts like bridging agent between catheter surface and drugs; it also allows the drug mixtures to get released from the surface very stable. So that the concentrations of the drugs would get released at sustained rate with an initial drug burst concentrations. To evaluate the biofilm producing capability of the test organisms, Microtitre plate assay was employed. The qualitative antibacterial activity of the coated catheters was evaluated against the test organisms (*Escherichia coli*, *Acinetobacter baumannii*, *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Candida albicans*). Good and evident inhibitory zones around the coated catheters were found potential in preventing the growth of biofilm producers. In conclusion, the obtained results revealed that the catheter surface modified with antibacterial coatings have prevented catheter-associated biofilm producing organisms.

**Keywords:** Intravascular, Biofilm, Moxifloxacin, Ornidazole, DL-lactic acid,

## INTRODUCTION

Eradicating the device-associated biofilm forming organisms and its associated proteins are highly complicated in healthcare sectors[1]. It was reported that the biofilm producers are highly (1000-fold) resistant than free-floating organisms[2]. The reason for their resistivity was described critically due to different complex factors like expression of specific genes that codes for drug resistance and biofilm formation[5].

Biofilm tolerance is of major clinical importance because more than 60% of the bacterial infections currently treated by physicians in the developed world are considered to involve biofilm formation[6]. The diseases like cystic fibrosis, endocarditis, device-related infections, and ventilator-associated pneumonia are considerably complicated by the formation of these biofilms, which are resistant to most current antimicrobial therapies[7].

Certain bacteria, such as *Pseudomonas aeruginosa*, can exist as biofilms on a variety of surfaces, including tissues and medical devices. Here, the bacteria cluster together with an extracellular matrix that often includes exopolysaccharide (EPS), proteins, and DNA[8], thereby providing an effective protection barrier against host immune responses and antibiotics. Each of these exopolysaccharides has been found to be involved in biofilm formation[9].

*Staphylococcus epidermidis* was reported as a representative biofilm producing organism in causing medical device-related infections[10]. The onset of infection and the clinical complication depends on the type of catheter and its insertion site[11]. Bacteriuria is highly associated with *S. Epidermidis* in case of repeated use of urinary catheters[12], and prosthesis-related infection in joint arthroplasty cases[13]. Biofilm formation by this organism was considered as multifactorial process solely dependent upon PIA expression[14,15]. PIA, a linear ß-1,6-linked glucosaminoglycan coupled with N-acetylglucosamine residues identified as the significant component which allows the biofilm producer for intercellular adhesion[16,17].

Biofilm expression due to the action of PIA is influenced by different factors, very importantly the use of several antibiotics[18]. The structural genes required for the PIA expression is encoded in icaR locus operon (icaADBC genes)[19]. The icaR genethus encodes a transcriptional repressor which was involved in the ica operon expression and biofilmformation[20].

Based on these perspectives, an antibacterial coating method was employed using two different set of drugs with a grafting carrier on the intravascular catheter surface. The drugs are selected based on their similar mode of action on inhibiting DNA replicative enzymes of biofilm producing organisms.

## MATERIALS AND METHODS

Five biofilm producing organisms (*Escherichia coli*, *Acinetobacter baumannii*, *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Candida albicans*) were obtained from a diagnostic laboratory at Coimbatore, Tamil Nadu, India. All laboratory work was carried out in the Department of Microbiology Laboratory, Sree Narayana Guru College, Coimbatore, Tamil Nadu, India.

### Evaluating the biofilm production of test organisms (Microtitre plate method)[21]

The evaluation was done using the method described by Christensen et al. (1985)[21]. In brief, all the test organisms (*Escherichia coli*, *Acinetobacter baumannii*, *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Candida albicans*) were allowed to grow in a 96-well microtitre plate for 24h. All the wells were rinsed to remove unbound cells. A dye solution was prepared (0.1% crystal violet solution) and 125µl of this standard was added to each well and incubated. The dye was removed by

washing successively with sterile distilled water. About 200µl of 95% ethanol was added to remove the bound dyes from each stained well. The wells were covered and incubated for 60min at 28°C.The bound dyes were removed and added onto a fresh titre plate. The colour intensity obtained was measured as optical density at a wavelength of 600nm using ELISA reader. In Table-1, the classification of biofilm index was presented.

**Anti-biofilm coating of intra vascular catheter materials using antibiotics[22]**

Anti-biofilm coating of intravascular catheter materials was carried out under strict aseptic conditions using a drug combination; each being from a different group. In brief, a known concentration Moxifloxacin (fluoroquinolone drug) and ornidazole (nitroimidazole drug) was selected and added with molten polyethylene glycol (PEG). PEG was used for a drug-slurry preparation and the resulting slurry was homogenized in a magnetic stirrer. The catheter samples were coated twice with intermittent drying by dipping inside the drug and polymer slurry mixtures. Following this protocol, the catheter samples were immersed into a carrier solution (DL- lactic acid was used as a drug-carrier molecule). All the samples were stored under freezing conditions and finally dried at room temperature prior testing.

**Evaluating the qualitative antibacterial activity of coated IVC materials[23]**

Antibacterial activity of all the coated catheter samples was qualitatively evaluated. Coated catheters were sterilized and placed over Mueller-Hinton agar (MHA) surface which was seeded with test organisms. All the plates were incubated at 37°C for 48h. Qualitative antibacterial activity of the coated catheters was identified by the inhibitory zones.

**Bio-statistical analysis to determine the effect of antibacterial drug on bacterial growth**

A non-parametric test (Chi-square) was used as a bio-statistical tool to determine the effect of antibacterial drug on bacterial growth. The hypothesis selected ($H_0$) was that "There is significant effect of antibacterial drug on the test organisms". The difference in the size of bacterial inhibitory zones between the antibacterial drug coated and uncoated catheter materials were statistically calculated with $P<0.05$ considering significant.

## RESULTS AND DISCUSSION

**Ability of the test organism to produce biofilm**

Microtitre plate method was employed to evaluate the ability of each test organism to produce biofilm. The biofilm production of each organism was compared with the standard index value (Table 1) and presented in Table 2. These standard biofilm index values were earlier reported in Christensen *et al*., (1985). When compared to the standard values in Table 1, four organisms [(*S. epidermidis* (0.252)*, S. aureus* (0.292), *E. coli* (0.293) and *Pseudomonas aeruginosa* (0.265)] showed OD values greater than 0.240. Hence, these organisms were considered as high biofilm producers. *Proteus mirabilis* showed moderate biofilm index value of 0.195. Difference in the biofilm production was correlated with the obtained OD values of crystal violet dye that was absorbed by the organism in the microtitre well. In Fig-2, the image showed the difference in the colour intensities of each organism that emphasizes the biofilm production.

According to Hassan *et al*.[24] the microtitre plate test is a more quantitative and reliable method for the identification of biofilm producing bacterial species when compared to other similar type of methods (Congo Red agar method and Borosilicate tube method). The researchers also recommended using this method as a common screening method for detection of biofilm producers in diagnostic laboratories. During their analysis, similar differentiation in biofilm production by the organisms was observed. Among the 110 clinical isolates, the researchers found 22.7% of high biofilm producers, 41% of moderate and 36.3% of weak biofilm producers. In another study carried out by Donlon[25] similar type of biofilm production was observed from the urinary catheters.

**Qualitative antibacterial activity of coated catheter materials**

The inhibitory zone measured in millimetres for moxifloxacin-ornidazole drug coated catheter materials against each test organisms were presented in Table-3. The antibacterial drugs and the carrier coated catheter samples (DCC) showed significant inhibitory zones. The zones were ranged from 14mm to 30mm against all the test organisms. Whereas, no inhibitory zones was observed for the uncoated materials. The drug and carrier coated samples showed maximum inhibitory zones of 30mm and 29mm against *Acinetobacter baumannii* and *Escherichia coli*respectively. Other biofilm producers, *Staphylococcus aureus*, *Pseudomonas aeruginosa* and *Candida albicans* also showed significant inhibitory zones measuring 25mm, 24mm and 26mm respectively. In Fig.1a, 1b, 1c, 1d and 1e, the qualitative antibacterial activity indicating the clear inhibitory zones around the *drug-carrier* coated IVCs against the test organisms were presented.

The rationale of combination of moxifloxacin-ornidazole was based on the fact that quinolones and imidazole derivatives act synergistically. This could be due to action of drugs on different sites on the bacterial DNA. A primary effect of quinolones is inhibition of bacterial DNA synthesis in the presence of competent RNA and protein synthesis[26]. According to Bharadwaj *et al*.[27] fluoroquinolone and nitroimidazole drugs in combination inhibits the activity of one of the A-subunits of the bacterial enzyme DNA gyrase, which is responsible for the negative super coiling of DNA, an essential conformation for DNA replication in the intact cell. Fluoroquinolone inhibits the activity of one of the A-subunits of the bacterial enzyme DNA gyrase, which is responsible for the negative supercoiling of DNA, an essential conformation for DNA replication in the intact cell. This inhibition of DNA gyrase activity is lethal to the bacterial cells. The 5-nitro group of imidazole undergoes reductive transformation to an active intermediate, which then exerts an inhibitory or lethal effect against DNA. Not only is DNA synthesis inhibited but the reduced metabolite also causes a loss of the helical structure of DNA with subsequent DNA strand breakage. Other reduction-oxidation processes within anaerobic organisms may also be inhibited, which also contribute to cell death. It is primarily active against obligate anaerobic microorganism. Under strictly anaerobic conditions, it also has an effect on facultative anaerobic organisms[28].

**Table 1: Classification of biofilm formation**

| Mean OD values | Biofilm formation | Biofilm index |
|---|---|---|

| | | |
|---|---|---|
| <0.120 | Nil | Non / weak |
| 0.120-0.240 | Moderately | Moderate |
| >0.240 | Strong | High |

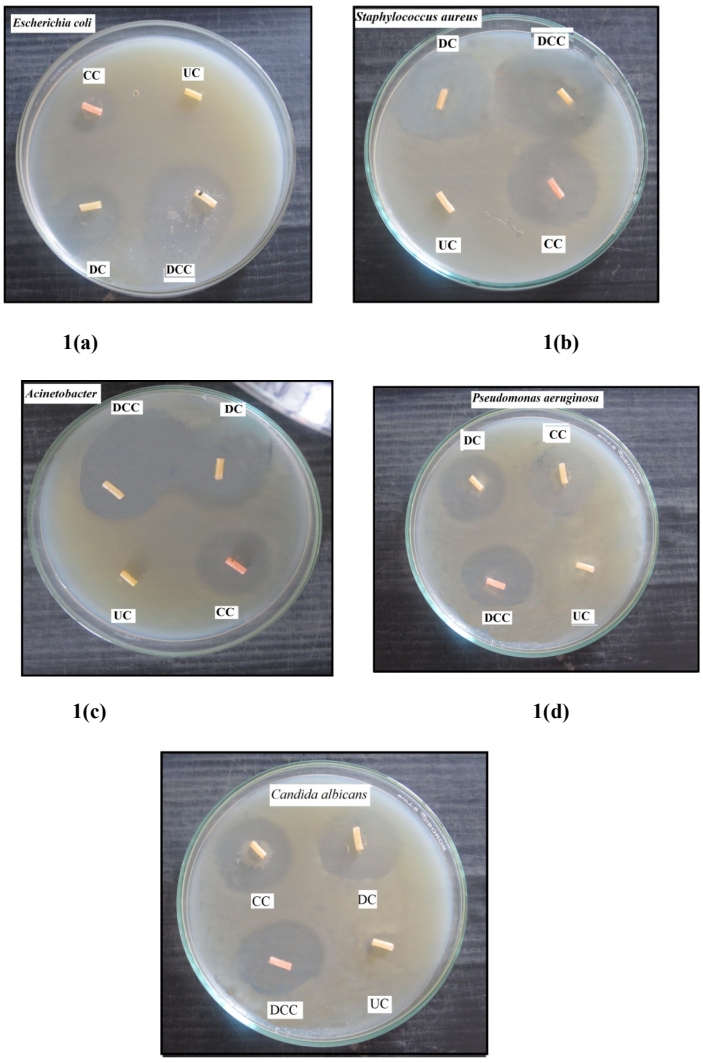
**Table 2: Screening test bacteria for biofilm formation by MTP method**

| Test Bacteria | Biofilm formation (OD 570nm) | Biofilm index |
|---|---|---|
| Control $C_1$ (Crystal violet) | 0.08 | weak |
| Control $C_2$ (Nutrient broth) | 0.09 | weak |
| *S. epidermidis* (ATCC 35984) | 0.252 | High |
| *S. aureus* (ATCC 29213) | 0.292 | High |
| *E. coli* (ATCC 43894) | 0.293 | High |
| *P. mirabilis* (ATCC 49565) | 0.195 | Moderate |
| *P. aeruginosa* (ATCC 700829) | 0.265 | High |

Biofilm Index - <0.120: Weak, 0.120-0.240: Moderate, >0.240: High

**Table 3: Assessing the qualitative antibacterial activity of dip-coated materials**

| Sl. No | Sample | Zone of inhibition in mm | | | | |
|---|---|---|---|---|---|---|
| | | ***Escherichia coli*** | ***Staphylococcus aureus*** | ***Acinetobacter baumannii*** | ***Pseudomonas aeruginosa*** | ***Candida albicans*** |
| **1** | **Uncoated catheter (UC)** | 0 | 0 | 0 | 0 | 0 |
| **2** | **Drug coated (DC)** | 18 | 22 | 23 | 21 | 24 |
| **3** | **Carrier coated (CC)** | 14 | 20 | 19 | 22 | 21 |
| **4** | **Drug carrier coated (DCC)** | 29 | 25 | 30 | 24 | 26 |




**1(a)** **1(b)** **1(c)** **1(d)** **1(e)**

**Figure 1: Assessing the qualitative antibacterial activity of dip-coated materials**

**Bio-statistical determination of the effect of antibacterial drug on bacterial growth**

The effect of antibacterial drug against the bacterial growth was determined using a non-parametric chi-square bio-statistical test method. The difference in the size of bacterial inhibitory zones

between the antibacterial drug coated and uncoated catheter materials was selected and statistically calculated with $P<0.05$ considering significant. The coated materials showed more inhibitory zones than the uncoated materials. During the statistical analysis, the calculated value was found significantly less than the table value; hence the designed hypothesis was accepted. The statistical survey of the research proved the qualitative antibacterial activity of thedrug coated catheter materials.

## CONCLUSION

Intra vascular catheter associated infection accounts for approximately 35% of infections in the health-care center. Several reports reasoned for the infections as the surface colonization of catheters by biofilm producing organisms. The present research was aimed to prevent the biofilm organisms by surface modification of the catheters by coating with two types of drugs and a carrier molecule. The antibacterial activity of the coated materials proved the anti-biofilm properties of the drug and carrier mixtures against the test organisms. To conclude, the results showed the anti-biofilm activity of drug and carrier combinations in the presence of a polymer, PEG. The biocompatibility of the antibacterial drug coated materials can be studied as future perspective in order to know the accurate concentrations essential to prevent the biofilm formation without any tissue toxicity.

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## REFERENCES

1. Costerton W,Veeh R, Shirtliff M, Pasmore M, Post C, Ehrlich G.The application of biofilm science to the study and control ofchronic bacterial infections. J. Clin. Invest. 2003; 112: 1466–1477
2. Gilbert P, Das J, Foley I. Biofilm susceptibility to antimicrobials. Adv. Dental. Res. 1997; 11: 160–167
3. O'Gara JP. ica and beyond: biofilm mechanisms and regulation in *Staphylococcus epidermidis* and *Staphylococcus aureus*. FEMS Microbiol. Lett. 2007; 270: 179–188
4. Maira-Litra´n T, Allison DG, Gilbert P. An evaluation ofthe potential of the multiple antibiotic reistance operon (mar) andthe multi-drug efflux pump acrAB to moderate reisistancetowards ciprofloxacin in Escherichia coli biofilms. J Antimicrob Chemother. 2000; 45: 789–795
5. Roberts ME, Stewart PS. Modelling protection from antimicrobial agents in biofilms through the formation of persister cells. Microbiol.2005; 151: 75–80
6. Fux CA, Costerton JW, Stewart PS, Stoodley P. Survival strategies of infectious biofilms. Tr.Microbiol.2005; 13: 34–40
7. Tart AH, Wozniak DJ. Shifting paradigms in Pseudomonas aeruginosa biofilm research. In: Romeo T (ed) Bacterial biofilms Current topics in microbiology and immunology. Springer-Verlag, Berlin, Heidelberg, 2008; pp 193–206
8. Bjarnsholt T, Nielsen TT, Hoiby N, Givskov M. Interference of Pseudomonas aeruginosa signalling and biofilm formation for infection control. Expert. Rev. Mol. Med.2010; 12:11-12
9. Ryder CM, Byrd and Wozniak DJ. Role of polysaccharides in *Pseudomonas aeruginosa* biofilm development. Curr. Opin. Microbiol. 2007; 10: 644–648.
10. Vuong C, Otto M.*Staphylococcus epidermidis* infections. Microbes Infect. 2002; 4: 481–489
11. Heilmann C, Peters G. Biology and pathogenicity of Staphylococcus epidermidis. In: Fischetti, V. A., Norvick, R. P., Ferretti, J. J., Portnoy, D. A., Rood, J. J. (eds) Gram positive pathogens. American Society for Microbiology, Washington, DC, 2001; p. 442–449
12. Warren, J. W. (2001) Catheter-associated urinary tract infection. Int. J. Antimicrob. Agents 17: 299–303
13. Gallo, J., Kolar, M., Novotny, R, Rihakova, P., Ticha, V. V. (2003) Pathogenesis of prosthesis-related infection. Biomedical Papers of the Medical Faculty University of Palacky, Olomouc, Czech Republic 147: 27–35
14. Hennig S, Nyunt Wai S, Ziebuhr W. Spontaneous switch to PIA-independent biofilm formation in an ica-positive Staphylococcus epidermidis isolate. Int. J. Med. Microbiol. 2007; 297: 117–122
15. Ziebuhr W, Hennig S, Eckart M, Kranzler H, Batzilla C, Kozitskaya S. Nosocomial infections by Staphylococcus epidermidis: how a commensal bacterium turns into a pathogen. Int. J. Antimicrob. Ag. 2006; 28: 14–20
16. Mack D, Nedelmann M, Krototsch A, Schwarzkopf A, Heesemann J, Laufs R.Characterisation of transposan mutants of biofilm-producing Staphylococcus epidermidis impaired in the accumulative phase of biofilm production: genetic identification of a hexosamine-containing polysaccharide intercellular adhesin. Infect. Immun. 1994; 62: 3244–3253
17. Mack D, Fischer W, Krototsch A, Leopold K, Hartmann R, EggeH, Laufs R. The intercellular adhesin involved in biofilm accumulation of Staphylococcus epidermidis is a linear beta-1,6-linked glucosaminoglycan: purification and structural analysis. J. Bacteriol. 1996; 178: 175–183
18. Schlag S, Nerz C, Birkenstock TA, Altenberend F, Gotz F. Inhibition of staphylococcal biofilm formation by nitrite. J. Bacteriol. 2007; 189: 7911–7919
19. Ziebuhr W, Heilmann C, Gotz F, Meyer P, Wilms K, Straube E, Hacker J. Detection of the intercellular adhesion gene cluster (ica) and phase variation in Staphylococcus epidermidis blood culture strains and mucosal isolates. Infect. Immun. 1997; 65: 890–896
20. Conlon KM, Humphreys H, O'Gara JP.icaR encodes a transcriptional repressor involved in the environmental regulation of the ica operon expression and biofilm formation in *Staphylococcus epidermidis*. J. Bacteriol. 2002; 184: 4400–4408
21. Christensen GD, Simpson WA, Younger JA, Baddour LM, Barrett FF and Melton DM. Adherence of cogulase negative *Staphylococci* to plastic tissue cultures: a quantitative model for the adherence of staphylococcito medical devices. J. Clin.Microbiol. 1985; 22: pp.996–1006.
22. Boccaccini AR, Stamboulis AG, Rashid A, Roether JA. Composite surgical sutures with bioactive glass coating. J. Biomed. Mater. Res. B. Appl.Biomater. 2003; 67: pp. 618–626.
23. El-Rehewy MK, El-Feky MA, Hassan MA, Abolella HA, Abolyosr A, El-Baky RMA, Gad GF. *In vitro* efficacy of ureteral catheters impregnated with ciprofloxacin, N-acetylcysteine and their combinations on microbial adherence, Clinical Medicine: Urol. 2009; 3: pp.1–8.
24. Hassan A,Usman J, Kaleem F, Omair M, Ali Khalid, Iqbal M. Evaluation of different detection methods of biofilm formation in the clinical isolates. Braz. J. Infect. Dis. 2011; 15(4): 305-311.
25. Donlan RM. Biofilms and device-associated infections. Emerg. Infect. Dis. 2001; 7(2):277-281.

26. Hooper DC and Wolfson JS. Mode of action of the quinolone antimicrobial agents: review of recent information. Rev. Infect. Dis. 1989; 5: 902-911.
27. Bharadwaj R, Vidya A, Dewan B, Pal A. An *in vitro* study to evaluate the synergistic activity of norfloxacin and metronidazole. Ind. J. Pharmacol.2003; 35: 220-226
28. Dollery C. (1999) Therapeutic Drugs, Churchill Livingstone: Edinburgh, 2:137-140.

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