Biosynthetic Engineering of Novel Multifunctioning Electroactive Bacterial Cellulose-Carbon Nanotube Therapeutic Bandages for Rapid Clearance of Vancomycin-Intermediate Staphylococcus aureus

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Staphylococcus aureus (SA) kills over 330,000 people yearly, is becoming increasingly resistant to antibiotics, and can stop wounds from healing. This study engineered bacterial cellulose-carbon nanotube (BC-CNT) bandages to produce electrochemical species, which rapidly eliminated vancomycin-intermediate SA. Komagataeibacter sucrofermentans synthesized a BC membrane at an air-liquid interface. Then, carboxyl-functionalized multiwalled CNTs were integrated into decellularized BC with sonication, rotational incubation, and an FDA-approved surfactant concentration. This created stable and electrically conductive BC-CNT bandages. The electric potential and ionic flux across BC-CNT was modeled using principles of space-charge density and mass transport. Tetrapolar chronoamperometry standardized the electric potential of the BC-CNT bandages for in vitro experimentation and validation. Following treatment with electroactive BC-CNT, scanning electron microscopy of SA around the terminal connection of the Cu working electrode (W.E.) revealed a high degree of cellular stress. In areas of reduced pH around the W.E., electrified BC-CNT prevented SA from forming macro-scale biofilms and increased SA susceptibility to vancomycin. This suggests that the release of Cu ions, generation of reactive oxygen species through voltage-induced hydrolysis, and cross migration of electrolytic ions are active killing mechanisms in the bandage. After a single hour of exposure involving the highest concentration of vancomycin and biocompatible potential, biofilm-forming capacity decreased by over 91%. ANOVA testing confirmed statistical significance. These results advance applications of electrochemistry in medicine and create new directions to overcome antibiotic-resistant infections.

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First Award of $5,000

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