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Unprecedented Eradication of Biofilms on Flexible Endoscopes Using Cold Atmospheric Plasma-Aerosol

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ABSTRACT

Introduction: Sterilization of medical equipment is critical to prevent healthcare-associated infections, yet conventional methods often fail against resilient biofilms on heat-sensitive devices. However, effective low-temperature alternatives that eradicate biofilms without damaging materials remain elusive. In this study, we demonstrate the unprecedented efficacy of cold atmospheric plasma-aerosol (CAP-A) in sterilizing biofilm-contaminated endoscopes.

Materials and Methods: We exposed *Pseudomonas aeruginosa* and *Staphylococcus aureus* biofilms on flexible endoscopes to CAP-A generated from a helium-oxygen mixture at room temperature. Treatment durations ranged from 5 to 15 minutes, followed by viability assessments via colony-forming unit counts and confocal microscopy.

Results and Discussion: CAP-A treatment reduced biofilm viability by over 6 log units (99.9999% inactivation) within 10 minutes, compared to less than 2 log units for hydrogen peroxide vapor (n = 12; $p < 0.001$). Reactive oxygen and nitrogen species penetrated biofilms up to 50 µm deep, resolving structures at 1 µm resolution via microscopy. No material degradation occurred, with surface integrity preserved (>99% similarity to controls). Against multi-species biofilms, inactivation reached 7 log units, establishing superior performance over prevailing low-temperature methods.

Conclusion: The approach suggested in our study establishes CAP-A as a transformative sterilization technique for thermolabile medical devices, paving the way for reduced infection rates in clinical settings.

Keywords: Biofilm inactivation, Cold atmospheric plasma, Endoscope sterilization, Low-temperature disinfection, Reactive species

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