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Cold Atmospheric Plasma in Chronic Wound Healing and Cancer Therapy: Mechanisms, Clinical Applications, and Future Outlook

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ABSTRACT

Introduction: Cold atmospheric plasma (CAP) has emerged as an innovative non-thermal biomedical technology capable of influencing cellular processes through controlled generation of reactive oxygen and nitrogen species. By providing antimicrobial, immunomodulatory, and tissue-regenerative effects without thermal damage, CAP offers unique advantages over conventional therapeutic approaches. Its clinical relevance is recognized in chronic wound management and cancer therapy, where microbial resistance, delayed healing, and tumor adaptability remain ongoing challenges.

Materials and Methods: A systematic literature review was performed using PubMed, Scopus, and Web of Science, focusing on studies published from 2020 to 2025. After applying predefined inclusion and exclusion criteria, 87 studies were included. Data extraction covered CAP device specifications, mechanistic pathways, preclinical and early clinical outcomes, and reported safety profiles. The review synthesized mechanistic insights with therapeutic performance across both clinical domains.

Results and Discussion: In chronic wound applications, CAP consistently demonstrated reductions in microbial biofilms including multidrug-resistant organisms while promoting angiogenesis, enhancing microcirculation, and accelerating re-epithelialization. In oncology, CAP induced apoptosis, enhanced immunogenic cell death, modulated redox signaling, and disrupted tumor-supportive biochemical pathways, leading to suppressed tumor progression in preclinical models. Despite encouraging findings, translation to routine clinical practice is limited by device heterogeneity, variability in exposure parameters, and insufficient long-term safety data.

Conclusion: Evidence to date supports CAP as a versatile and clinically promising adjunct for wound healing and cancer therapy. Future progress depends on developing standardized treatment protocols, harmonizing regulatory guidelines, and implementing large-scale randomized clinical trials. Combining CAP with established therapeutic modalities may further enhance its clinical impact and accelerate adoption in modern medical practice.

Keywords: Cancer therapy, Cold plasma, Reactive oxygen and nitrogen species, Regenerative medicine, Wound healing

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