Novel micro-cold atmospheric plasma device for cancer treatment

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Motivation of the Study

Plasma medicine is an innovative and emerging field of interdisciplinary research that combines biology, chemistry, physics, and medicine. Cold atmospheric plasma (CAP) can be applied to living tissues and cells, which has emerged as a novel technology for cancer therapy[1,2]. The efficacy of CAP in proposed applications relies on the synergistic action of reactive oxygen species (ROS) and reactive nitrogen species (RNS)[3,4]. A low dose of ROS and RNS was reported to be able to induce the cell proliferation as well as cell death, while a high dose can damage proteins, lipids, DNA, and induce apoptosis. Fig. 1 shows sketch of CAP jet and DBD configuration with sample treated.

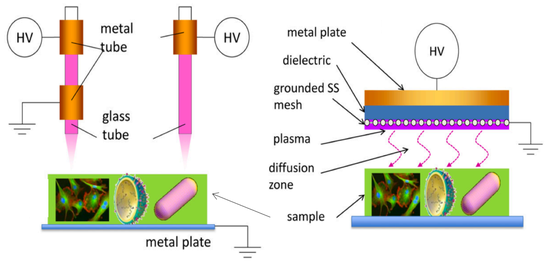

Figure 1. Sketch of indirect plasma jet and DBD configuration with sample treated

In this work, a μCAP device employing helium gas was developed. The main objective of this research is to investigate the effect of μCAP on cancer cells in vitro and vivo studies.

In Vitro Experimental Setup

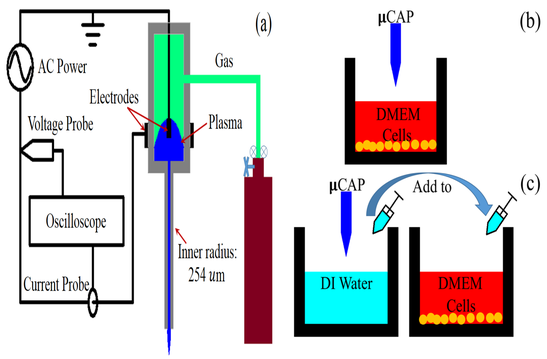

Figure 2. (a) Schematic representation of micro-sized cold atmospheric plasma setup. (b) Micro-sized cold atmospheric plasma (μCAP) direct treatment: μCAP directly treated DMEM containing cells. (c) μCAP indirect treatment: μCAP treated DI water and remove it to DMEM containing cells (70% DMEM + 30% treated DI water) .

Electron Density and Emission Spectrum

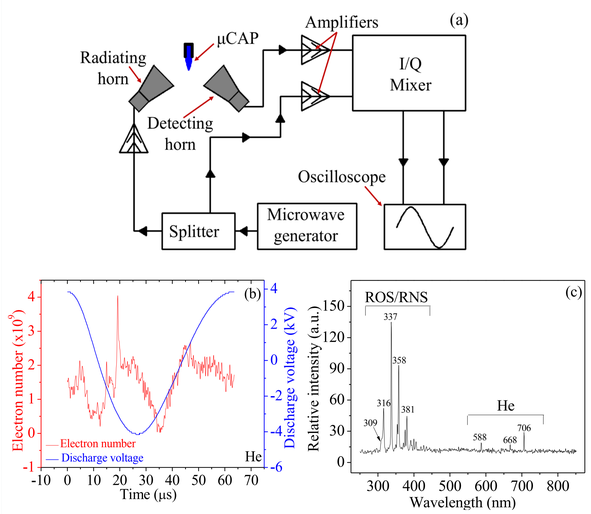

Figure 3. (a) The schematics of Rayleigh Microwave Scattering System (RMS) experimental setup, (b) electron number per period discharge of He μCAP (2.4×10^9), and (c) Optical emission spectrum detected from the He μCAP using UV-visible-NIR.

RNS Concentration: NO_2^-

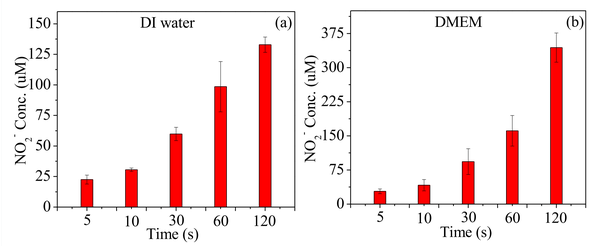

Figure 4. RNS concentration in μCAP treated DI water and DMEM: treat DI water (a) and treat DMEM (b). (n=3)

Relative Methylene Blue: OH*

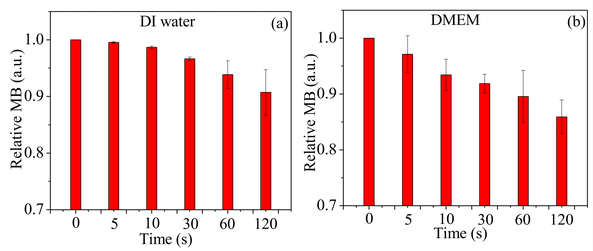

Figure 5. Relative MB concentration in μCAP treated DI water (a) and DMEM (b). (n=3)

ROS Concentration: H_2O_2

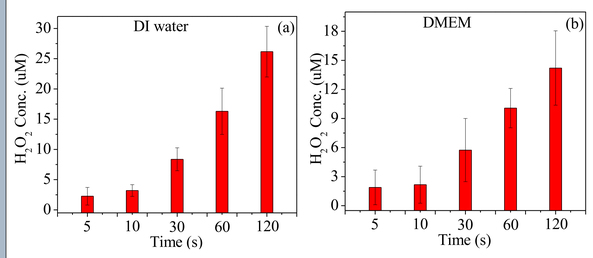

Figure 6. ROS concentration in μCAP treated DI water (a) and DMEM (b). (n=3)

Cell Viability

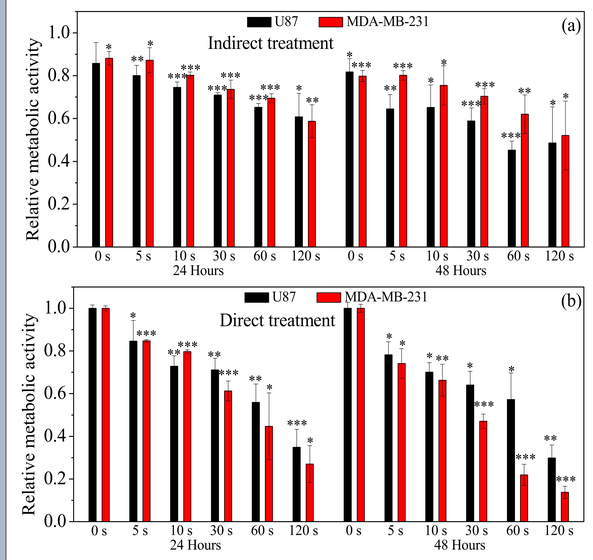

Figure 7. Cell viability of U87 and MDA-MB-231 after 24 and 48 hours' incubation with μCAP indirect (a) and direct (b) treatment during 0, 5, 10, 30, 60, and 120 seconds' treatment. (n=3)

In Vivo Experimental Setup

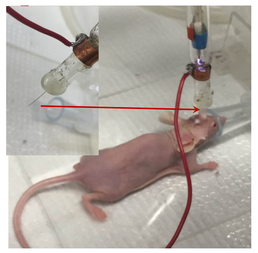

Figure 8. Photograph of a new μCAP for plasma delivery through an intracranial endoscopic tube to target glioblastoma tumors in the mouse brain.

ROS and RNS Concentration

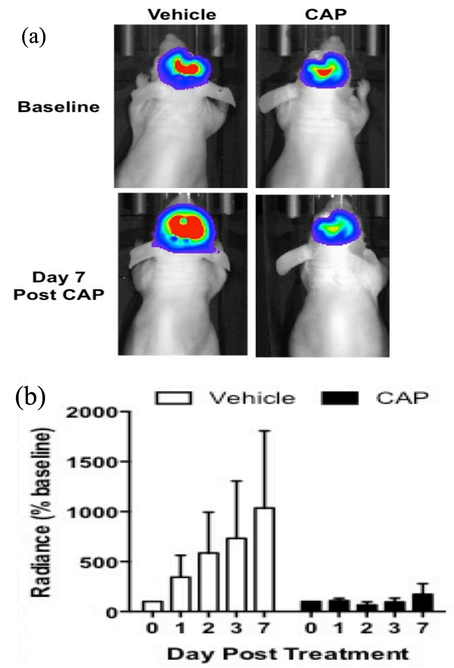

Figure 9. (a) Representative bioluminescence images in vivo illustrating U87 tumor volume at baseline and 1 week following μCAP or vehicle (helium) treatment. (b) The tumor volume in control treated animals aggressively increased following treatment, whereas μCAP delivery maintained tumor volume at basal levels. (n=3)

Conclusions

In summary, it has been demonstrated a newly developed μCAP for cancer therapy. The in-vitro results show that the μCAP could induce apoptosis in cancer cells and could inhibit the proliferation of the cells, which indicates that the impact is more significant in cell apoptosis by synergistic effect of short-/long-lived species and radicals. The in vivo results demonstrated that the μCAP suppressed the tumor growth and induced apoptosis in the tumor cells. The results of this study is a primary research for utilizing μCAP inside the patient's body in the future.

References

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