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Corona plasma pen using streamer discharge in air induces disinfection and selective anticancer effects

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Antibacterial or anticancer effects of cold atmospheric plasmas (CAP) and plasma activated water or media (PAW or PAM) are generally established. We present biomedical effects of a portable low-cost plasma pen operating with streamer corona discharge in ambient air. It generates CAP of low power (<1W) producing various reactive oxygen and nitrogen species (RONS) [1]. Such corona discharge has been successfully tested for biofilm eradication on surfaces [2] or antibacterial effects in water solutions [3]. The electrical parameters of the corona pen were characterized. The corona discharge induces the ionic wind, which determines the flux of RONS towards the solid or liquid target. Ionic wind velocity was measured, its spatial distribution visualized, and RONS delivered into PBS quantified for various modes of the corona pen operation.

Antibacterial effects of the corona pen were tested *in vitro* using scratches mimicking cutting wounds on agar plates with *E. coli*. Longer plasma treatment resulted in wider decontaminated scratch areas, but the effect was weaker when bacteria were pre-grown on agar for more than 6 h. Wound healing effects of the corona pen were confirmed by a case study on a large surface wound.

Induction of apoptosis and cell viability reduction was demonstrated by PAM and CAP activated PBS (pPBS) applied to epithelial melanoma cells A375 and compared with nonmalignant human dermic fibroblasts HDFa. The preliminary results indicate better resistance of the nonmalignant than cancer cells to PAM/pPBS. The breakthrough result obtained with the corona pen was a selective apoptosis induction on cancer cells, both by CAP and PAM effects on human gastric adenocarcinoma MKN-45 and other malignant and nonmalignant cells. Extensive experiments using enzyme inhibitors, reactive species scavengers and donors, mimetics, and gene (enzyme) knockdowns, allowed the development of a detailed mechanistic picture of CAP and PAM induced selective apoptosis of tumor cells relative to nonmalignant cells. Primary $^1O_2$ is produced through the complex interaction between NO_2^- and H_2O_2. $^1O_2$ then inactivates membrane-associated catalase molecules on some tumor cells. These tumor cells allow locally surviving cell-derived, extracellular H_2O_2 and $ONOO^-$ to form secondary $^1O_2$ that continue to inactivate catalase on the adjacent cells. A key conclusion is that tumor cell-generated RONS play the key role in inactivating protective catalase and establishing apoptosis-inducing RONS signaling after an initial limited generation of $^1O_2$ by CAP-derived RONS [4].

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