دومین کنگره پلاسما پزشکی ایران
The 2nd Congress on Plasma Medicine
DECEMBER 11-12,2025
۲۱ و ۲۰ آذر ماه ۱۴۰۴
دبیرخانه دائمی کنگره پلاسما پزشکی ایران
www.plasmamedsym.ir

Methods for Characterizing and Comparing Medical Plasma Jet Devices

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Citation:
Bakhtiyari Ramezani M, Nasiri P, Shakeri F. Ebrahimnezhad Darzi R, Rezanejad M. Methods for Characterizing and Comparing Medical Plasma Jet Devices. *Iran Biomed J*. Supplementary (2-2026): 14.

ABSTRACT

Introduction: Accurate, harmonized characterization of medical cold atmospheric plasma (CAP) jets is essential for ensuring safe and effective clinical translation. This study presents standardized, side-by-side methods for comparing CAP jets to clarify how gas type, nozzle architecture, and operating conditions impact optical, electrical, thermal, and plume behavior. Key findings indicate marked differences in species production, electron parameters, delivered thermal power, and a nonlinear relationship between flow and plume length with three regimes.

Materials and Methods: We utilized a unified protocol that combined various techniques, including optical emission spectroscopy for species detection, Boltzmann plots, and line ratios for electron temperature, Stark-broadening Hα for electron density, electrical diagnostics (V_rms, I_rms, phase, active power), copper-plate calorimetry plus infrared thermography, ultraviolet (UV) photometry, ozone monitoring, and quantitative imaging of plume-length/shape, conducted under a 3 × 3 voltage-flow matrix.

Results and Discussion: Helium jets produced signals from He-I, N_2 (in single pulse and full negative signal modes), and OH; the multi-array configuration increased overall emission and OH signals. Argon jets showed strong Ar-I signals and increased OH production. The thermal power delivered was <0.5 W for single-He jets, ~1–2.5 W for multi-He jets, and >1 W for argon jets. The relationship between plume length and flow exhibited a nonlinear pattern, characterized by laminar, transitional, and turbulent regimes. UV and ozone levels remained within safe limits.

Conclusion: A harmonized, multi-modal protocol enabled quantitative cross-comparison of CAP jets, revealing predictable links between gas type/design and performance. The findings provide practical guidance for selecting devices and determining operating conditions for medical applications, emphasizing the need for standardized measurement protocols to ensure reliable benchmarking of devices.

Keywords: Cold atmospheric plasma jet, Electron density, Electron temperature, Optical emission spectroscopy, Plasma jet characterization

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