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Ultra high-dose rate X-ray pulses emitted from a kilojoule plasma focus device induce larger cancer cell deaths than the conventional X-ray irradiation: Preliminary single dose and fractionation studies

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Radiation therapy has been a cornerstone in cancer treatment for decades, using ionizing radiation to target malignant cells. Commonly, cancerous tumors are treated with high radiation doses at tens to hundreds of Gray per hour (Gy/hr) dose rate, considering dose-fractionation to reduce cytotoxic effects on surrounding healthy cells. Despite this, cancer recurrence remains in many cases, driving exploration into alternative strategies like FLASH radiotherapy (FLASH-RT) [1-3]. FLASH-RT delivers moderate doses—around 8-10 Gy—in under a second, targeting tumors while minimizing harm to healthy cells. Yet, the effects of ultra-high dose rates (10^3 to 10^7 Gy/sec) on cancer cells are still largely uncharted.

In this study, several cancer cell lines were irradiated by pulsed X-ray at an ultra-high dose rate of ~10^7 Gy/sec, using a kilojoule plasma focus device (PF-2kJ) with total doses kept low (≤ 1 Gy). The included cell lines were colorectal cancer cells (DLD-1, HCT-116), breast cancer cells (MCF-7), and an ovarian cancer cell line HEY. A non-cancerous colorectal cell line, CCD-841-con, was also irradiated. The DLD-1 cells showed low-dose hyper-radio-sensitivity (LDHRS) at lower doses of pulsed X-rays than conventional irradiation, indicating heightened vulnerability. The HCT-116 cells exhibited LDHRS with pulsed X-rays (absent with conventional treatment [4]). The MCF-7 cells experienced increased cell death under pulsed irradiation, suggesting ultra-high dose rates may bypass radio resistance [5]. The ovarian cancer cells showed reduced proliferation in 2D cultures and fewer vasculogenic-mimic structures in 3D models with pulsed X-rays, hinting at broader tumor-disrupting effects. Interestingly, the non-cancerous colorectal cancer cell line, CCD-841-con, was unaffected by pulsed X-ray irradiation.

The study also explored dose fractionation with pulsed X-rays, delivering 10 pulses to reach 40 pulses in total. This approach yielded responses distinct from single-dose irradiation. Unlike traditional fractionation, which balances efficacy and safety, pulsed ultra-high dose rates introduce a new dynamic to this equation.

These findings suggest that ultra-high dose rate radiation may hold promise for advancing radiation therapy. By enhancing cancer cell destruction while potentially sparing healthy tissue, it could offer a path to more effective, less toxic treatments. The differential responses—such as LDHRS in colorectal lines, overcoming resistance in MCF-7, and disrupting tumor structures in ovarian cells—indicate that ultra-high dose rates might unlock unique therapeutic advantages. However, further research is essential to fully decode the underlying mechanisms and translate these initial insights into clinical practice. Continued research in this area may contribute to reshaping cancer care and improving outcomes for patients facing recurrence and resistance challenges.

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