Survival of tumor cells after proton irradiation with ultra-high dose rates.

Abstract:

Laser acceleration of protons and heavy ions may in the future be used in radiation therapy. Laser-driven particle beams are pulsed and ultra high dose rates of $>10^7$ Gy s$^{-1}$ may be achieved. Here we compare the radiobiological effects of pulsed and continuous proton beams. The ion microbeam SNAKE at the Munich tandem accelerator was used to directly compare a pulsed and a continuous 20 MeV proton beam, which delivered a dose of 3 Gy to a HeLa cell monolayer within $<1$ ns or 100 ms, respectively. Investigated endpoints were G2 phase cell cycle arrest, apoptosis, and colony formation. At 10 h after pulsed irradiation, the fraction of G2 cells was significantly lower than after irradiation with the continuous beam, while all other endpoints including colony formation were not significantly different. We determined the relative biological effectiveness (RBE) for pulsed and continuous proton beams relative to x-irradiation as $0.91 \pm 0.26$ and $0.86 \pm 0.33$ (mean and SD), respectively. At the dose rates investigated here, which are expected to correspond to those in radiation therapy using laser-driven particles, the RBE of the pulsed and the (conventional) continuous irradiation mode do not differ significantly.