Study of backbone and base pair bond breaking in DNA during proton beam irradiation

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Purpose: To study the damage to molecular bonds within hydrated and dry DNA caused by proton beam irradiation at the beam entrance (low linear energy transfer (LET) region) and the Bragg peak (high LET region) using x-ray photoelectron spectroscopy (XPS).

Methods: Dry DNA samples and samples dissolved in distilled water and were placed at the entrance (0 cm depth), in the dose build up region (10 cm depth), at the proton Bragg peak (BP) maximum (15.4 cm depth), and at the BP distal 80% depth (15.6 cm) within a high-density polyethylene (HDPE; ρ=0.96 g/cm^3) phantom. The samples were irradiated with protons which ranged in energy from a maximum of 150 MeV clinical proton beam that delivered 1 x 10^{11} protons/cm^2 down to 2 MeV and 1 x 10^{17} protons/cm^2 with the lower energy protons i.e., 2-3 MeV produced by a 5SDH-2 Pelletron@ made by National Electrostatics Corporation. Changes to the percentage of molecular bonds in the DNA phosphate backbone and base pairs were determined using XPS.

Results: We observed that in the entrance (0.55 kev/µm) and build up (0.91 keV/µm) regions the dominate form of DNA damage is through phosphate backbone bond breaks. At the depths of the BP maximum (~2.6 keV/µm linear energy transfer (LET)) and distal 80% falloff (LET > 2.6 keV/µm), backbone bond damage increased sharply for dry DNA, however for wet DNA base pair bond damage increases becoming dominant.

Conclusions: This sharp increase for base pair damage for hydrated DNA could provide information as to the importance of reactive oxygen species created in water promoting DNA damage. The increasing base pair damage might provide information for the relative biological effectiveness of proton beams as LET increases near the end of range.

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