Radioactivities in Solution by Particle Radiation can Increase Sister Chromatid Exchanges

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Abstract

Introduction

Non-radioactive atoms can become radioactive from a nuclear reaction when atoms are hit by other high energy particles. These radioactivations are observed in nuclear facilities and may result in health effects in humans. Protons, carbon-ions, and iron-ions are tested to verify this hypothesis.

Materials and Methods

Protons were accelerated to 70MeV in cyclotron (NIRS-930) at National Institute of Radiological Sciences (NIRS). Carbon-ions and iron-ions were accelerated to 290MeV/n and 500MeV/n respectively, in HIMAC (Heavy ion Medical Accelerator in Chiba) at NIRS. 60ml of sterilized Milli-Q ultra pure water or PBS were filled in Falcon T25 flasks and exposed to ionizing radiation. Radioactivities were measured by Aloka Geiger counter. 1ml of exposed solution were transferred into flasks culturing cells with 5ml medium immediately after exposure or 2 hours after exposure. CHO cells were synchronized into G1-phase 2 to 3 hours before transfer experiments by a mitotic shake-off method. To verify radical scavenger effects, DMSO (final 1% v/v) was added to cell culture 30 minutes before radioactive solution was transferred. In order to get differential staining, BrdU was added to cell culture after 1ml of radioactive solution was transferred. Cells were cultured for two cell cycles, and the second-post treatment metaphases were harvested with Colcemid treatment. SCE differential staining was carried out with Hoechst 332588 treatment, black light exposure on a 55°C heatblock, and 65°C 2xSSC treatment followed by Giemsa staining. More than 50 metaphase chromosomes were observed and scored under Zeiss Axiophot or Olympus BX51 microscope.

Results

Radioactivity in solution

0.1Gy to 100 Gy of proton, carbon-ions, and iron-ions were able to activate solution in a dose dependent manner. No clear differences of radioactivities between water and PBS were observed. Amount of activation per exposed doses were strongest in proton (Figure 1). Half-life of activation was approximately 20 minutes for all cases. Highest radioactivity was observed after 100Gy of proton exposure. It was approximately 1.5mSv/h and more than 1,000,000 CPM.

SCE induction by radioactive solution

SCE induction was depending on radioactivity of transferred solution. SCE induction was highest when 100Gy of proton exposed solution was transferred immediately after irradiation. SCE induction was generally lower when radioactive

solution was transferred 2 hours later. DMSO pre-treatment reduced SCE induction for both cell culture groups which had solution transferred immediately and 2 hours post-exposure. Pooled SCE data were plotted in Figure 2.

Discussion

Radioactivation was observed after hadron particle exposure having half-life of 20 minutes. The only radionucleide that has similar half-life to this is Carbon 13. Beta decay in Carbon 13 emits a positron that annihilates an electron, generating two gamma-rays with 0.511MeV. We assume these gamma-rays produce reactive free radicals that damage DNA and increase SCE. DMSO pre-treatment suppressed SCE induction and supports our hypothesis. Our experiments suggest low and high LET hadron particles can activate solution which leads to some genomic instability. It is possible that this process has some contributions to a bystander effect.

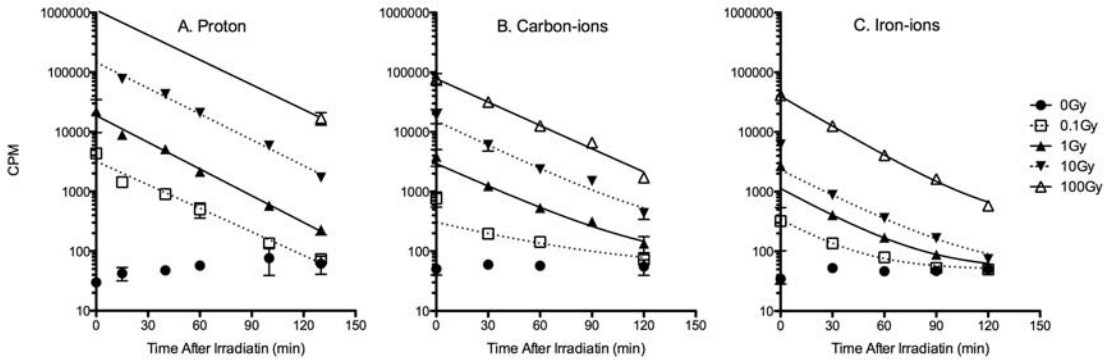

Figure 1. Radio-activation of average of water and PBS by accelerated particles. Dose response and time course of radioactivities. Half life of activity was approximately 20 min.

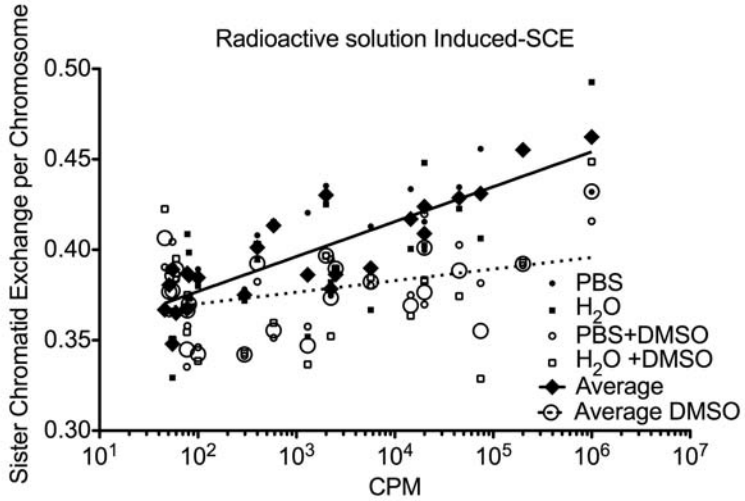

Figure 2. Sister chromatid exchange induction from radioactive solution. Trendlines were drawn for DMSO treated and non-treated pooled data.