Characterizing Radiation Dose Rate Effects on Human Lymphocytes

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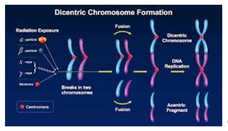
Introduction

- Radiation exposure has been a hazard with accidents in Chernobyl, Ukraine and, more recently, Fukushima, Japan.
- Nuclear power is still a significant energy source, giving more opportunities for further exposure events.
- Effects of both low and high doses of radiation range from chromosomal changes to increased cancer rates.
- Humans are exposed to both chronic and acute doses of radiation and the biological effects of chronic low dose rate exposure aren't well-understood.
- This study attempts to compare high dose rate (acute exposure) and low dose rate (prolonged exposure) effects upon chromosomes of affected lymphocytes. Very few studies have been done on the effects of chronic low dose rate radiation exposure.
- This study may lead to better understanding of how cells and tissues are affected by radiation and thus better diagnosis and treatment plans.

Background

- Dicentric chromosomes are caused by ionization energy causing double strand breaks and mis-rejoining of chromosomes.



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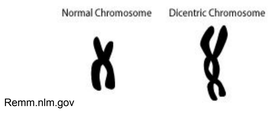
- The dicentric chromosome assay was utilized to evaluate the effects of low- and high-dose rate exposures on human lymphocytes.



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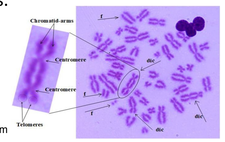

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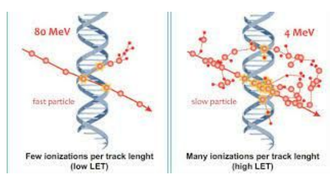
- Triage mode of scoring was used in the experiment in which 50 cells (or 30 dicentric chromosomes) are sufficient for rapid dose estimation.
- Radiation is measured in Gray (Gy) and dose rate is a measure of the rate at which energy is transferred to a targeted material (Gy/min).
- There are two kinds of Linear Energy Transfer (LET).

High-LET radiation, such as alpha particles and neutrons, generates densely ionizing events with a large amount of energy.

Low-LET radiation is from external electromagnetic radiation, and include x-rays and gamma rays which generate sparsely ionizing events.

- Gamma rays are high energy emissions from an excited nucleus after alpha or beta particle decay.



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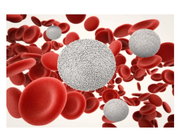
- Lymphocyte cells were used in the project due to their radiation susceptibility and their ease of growth in vitro.



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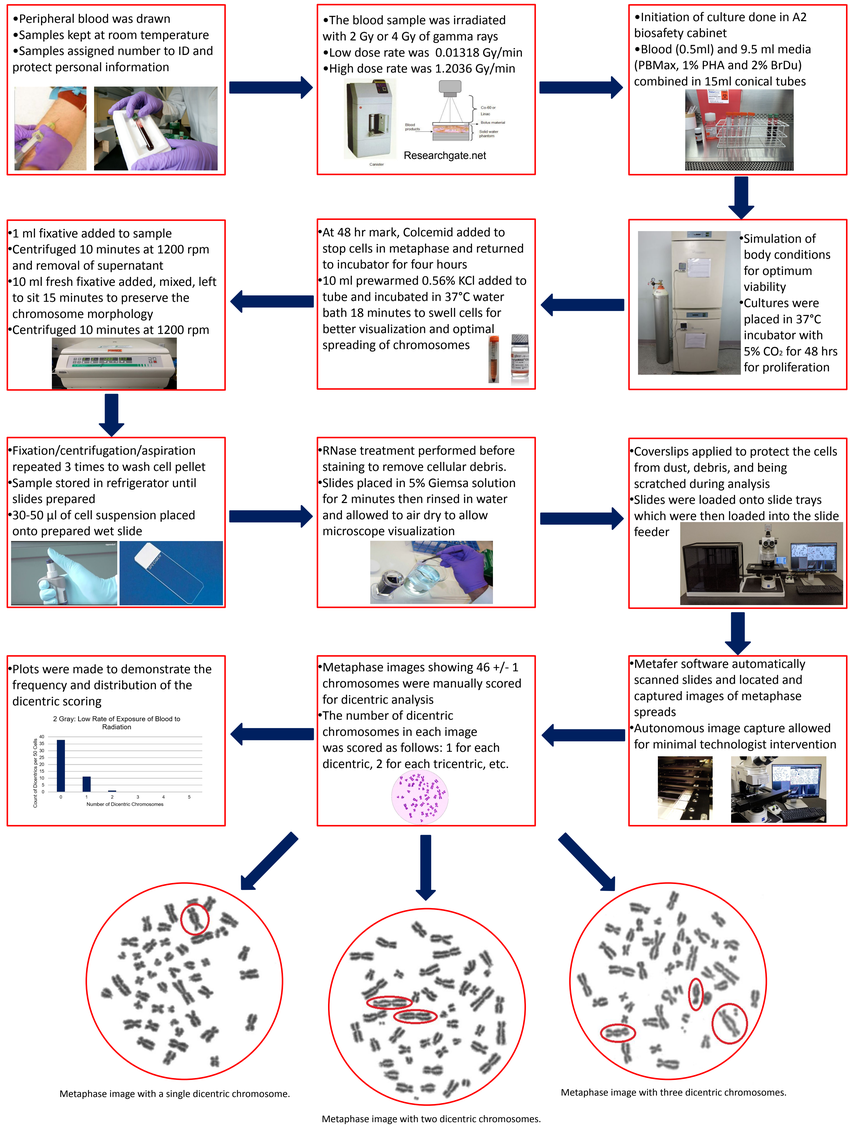
Materials and Methods



Metaphase image with a single dicentric chromosome.

Metaphase image with two dicentric chromosomes.

Metaphase image with three dicentric chromosomes.

References

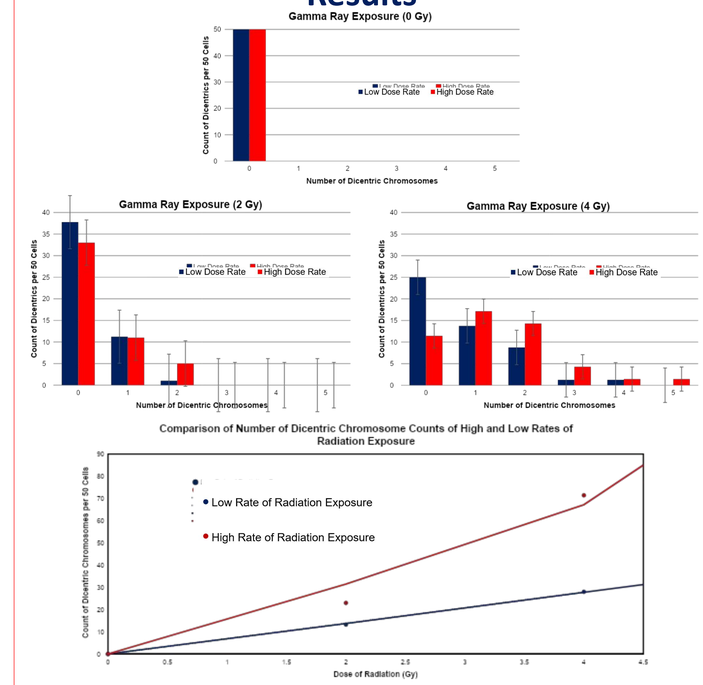
Adayabalam S Balajee[1], Maria Escalona[2], Carol J Iddins[2], Igor Shuryak[3], Gordon K Livingston[2], Don Hanlon[4], Nicholas Dainiak[1] "Development of electronic training and telescoring tools to increase the surge capacity of dicentric chromosome scorers for radiological/nuclear mass casualty incidents" Appl Radiat Isot. 2019 Feb; 144:111-117.

Adayabalam S Balajee[1], M Prakash Hande[2] "History and evolution of cytogenetic techniques: Current and future applications in basic and clinical research" Mutat Res Genet Toxicol Environ Mutagen. 2018 Dec;836(Pt A):3-12.

Adayabalam S Balajee[1], Tammy Smith[1], Terri Ryan[1], Maria Escalona[1], Nicholas Dainiak[1] "Development Of A Miniaturized Version Of Dicentric Chromosome Assay Tool For Radiological Triage" Radiat Prot Dosimetry. 2018 Dec 1;182(1):139-145.

Driver. (2020, June 14). Information on Linear Energy Transfer for X-ray Techs. CE4RT. https://ce4rt.com/rad-tech-talk/explaining-linear-energy-transfer/

Results



Conclusions

- Radiation dose dependent induction of dicentric chromosomes was observed in human lymphocytes after exposure to both low (0.01318 Gy/min) and high (1.2036 Gy/min) dose rates of Gamma rays.
- Frequencies of dicentric and polycentric chromosomes were higher in lymphocytes exposed to high dose rate than in those exposed to low dose rate Gamma rays.
- The dose response curve was linear for low dose rate exposure and linear quadratic for high dose rate exposure for both radiation doses tested. This initial observation needs to be verified with additional radiation dose points (0.25 Gy, 0.5 Gy, 1 Gy and 3 Gy).
- Differences were observed in the cellular distribution of dicentric and polycentric chromosomes between low and high dose rate exposures.
- Reduced induction of dicentric and polycentric chromosomes observed in low dose rate Gamma rays exposed cells was likely due to protracted exposure allowing more time for DNA repair.

Acknowledgements

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