Impact of Ionizing Radiation on the Expression of CDC25A Phosphatase in vivo

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ABSTRACT

Background and Objective: The cell division cycle 25 (CDC25) is a family of highly conserved dual-specificity phosphatases that activate cyclin-dependent kinase complexes. These complexes are the main cell cycle regulators. Mammalian cells, exposure to DNA damaging radiations such as ionizing radiation and ultraviolet light, prevent cell cycle progression by activation of checkpoint pathways and lead to cell death.

Methods: In this study, mice were exposed to different doses of ionizing radiation. Their total cellular protein was extracted from the bone marrow. After determining and matching the protein concentrations, CDC25A phosphatase levels were measured by western blotting.

Results: The results showed that exposure to different doses of ionizing radiation in vivo significantly increased the expression of CDC25A compared to control group (P <0.05).

Conclusion: Exposure to ionizing radiation increases the expression of CDC25A phosphatase, which increases the possibility of tumorigenesis in that area by increasing bone marrow cell proliferation.

Keywords: Cell Cycle, CDC25A, Ionizing Radiation, Cyclin-Dependent Kinase.
INTRODUCTION

Double-strand break (DSB) in the DNA is resulted from exposure to ionizing radiation that induces genomic instability, dysregulation of cell cycle and tumorigenesis (1, 2). Cyclin-dependent kinases (CDKs) are the key regulator of cell cycle progression. CDKs become inactivated via phosphorylation of their two residues on the loop binding to ATP (threonine-14 and tyrosine-15) by Myt1 and Wee1 kinases. When the cell cycle progression is dependent on the activity of CDKs, the dual-specificity phosphatase (CDC25) activates the CDK-cyclin complex that leads to cell cycle progression by removing the inhibitory phosphate from the CDKs (3). The cell division cycle 25 (CDC25) is a family of highly conserved dual-specificity phosphatases that activate the CDKC and regulate cell cycle. The family has three isoforms; CDC25A, CDC25B and CDC25C (4), with 40-50% identity (5, 6). The CDC25A interacts with many genes in the cell (Figure 1), and mostly causes activation of CDK2-cyclinA and CDK2-cyclinE complexes, which leads to G1 to S phase transition. However, it is also responsible for the G2 to M transition by activating CDK1-cyclinB (7, 8). CDC25A is predominantly expressed in the G1 phase and stabilized in mitosis by phosphorylation of CDK1-cyclinB. At the end of mitosis, CDC25A level reduces due to destruction caused by anaphase 10). Promoting complex/cyclosome ubiquitin (9, CDC25A is destroyed in embryonic stem cells after induction of DSBs by ionizing radiation (11). Today, the use of radiation and its application in human life are undeniable necessities. On the other hand, the biological side effects of radiation have always been of interest to researchers (12). When eukaryotic cells are exposed to DNA damaging agents such as ionizing radiation and ultraviolet (UV), they inhibit cell cycle progression by activating DNA damage checkpoints, leading to cell death (13).

CDC25A is a suitable target for damage response during mitosis because it accumulates during mitosis (14), and plays an important role in response to damage caused by DNA exposure to ionizing radiation (15, 16). Eliminating CDC25A suppresses cell proliferation and gives the cell a chance to repair the DNA. The exposure of eukaryotic cells to ionizing radiation activates checkpoints and stops the cell cycle (17). Although overexpression of CDC25A has been observed in a large number of cancers, the molecular mechanism of this overexpression is not clear (4). This study aimed to evaluate cell cycle suppression or progression and CDC25A expression level after exposure to different doses of ionizing radiation in vivo.

Figure 1 - CDC25A gene interacts with certain genes involved in the cell cycle
MATERIAL AND METHODS

The healthy female mice (without any infection) were used in this study. The animals used for experiments were kept in controlled temperature and humidity with access to food and water. All testing phases were approved by the Ethics Committee for Laboratory Animals at Golestan University of Medical Sciences, Iran. Test animals were divided into four groups of three and a control group. Each group was exposed to different doses of gamma-radiation including (1.25, 1.5, 1.75, 2). Gamma rays from cobalt-60 obtained from the radiotherapy center of the Golestan Province had dose rate of 67.55 cGy per minute. The exposure time was at the 2.13-3.55 min range, irradiated field size of 30 × 30 cm², and source-to-surface distances of 80 cm. The femoral bone marrow of the mice was removed and placed in test tubes. About 150 μl of lysis buffer [containing 5% SDS, 100 mM Tris-HCl (pH=7.4), 150 mM NaCl, 5 mM EDTA, 5% sodium deoxycholate, 10% glycerol] were added to the tubes containing bone marrow cells. Then, 10 μl of protease inhibitor cocktail was added to the samples. Pierce BCA protein assay kits (Thermo Fisher Scientific) and bovine serum albumin (BSA) were used to determine the concentration of cellular proteins and plotting the standard curve, respectively. The proteins were separated by SDS-PAGE electrophoresis on 12% gel based on the molecular weight. Then, the 5x sample loading buffer containing 10% SDS, 0.5% bromophenol blue, 60 mM of Tris-HCl (pH 6.8), 50% glycerol, and 14.4 Mm of 2-mercaptoethanol was added to each tube. The samples were placed at boiling temperature for 5 minutes. Then, 35μl of protein was loaded into each well for blotting. The protein samples were separated on 12% polyacrylamide gel with current of 110 volts for 45 minutes, and transferred to nitrocellulose membrane (Thermo) via the buffer (15.6 mM Tris-base, 120 mM glycine, 10% methanol with pH 8.4). Blots in the 3% skim milk along with phosphate buffer saline [(PBS) with final concentration of 0.1% Tween] were placed on a rotator for 2-3 hours at room temperature. The antibodies were diluted in 3% skim milk (1:1000 ratio) and used against CDC25A phosphatase at 4 °C, and then incubated in PBS-Tween (PBS-T). The blots were washed three times with PBS-T for 5, 10 and 15 minutes at room temperature. Then, the blots were incubated with HRP conjugated secondary antibody, goat anti-mouse IgG, diluted with 3% skim milk (1:2,000) in PBS-T for 1-2 hours at room temperature, on a rotator. The blots were washed and exposed to autoradiography film at various times, 5 minutes after incubation with enhanced chemiluminescence (ECL). Finally, the films were printed and observed. The data was analyzed by SPSS (version 19), using analysis of variance (ANOVA), Tukey’s honest significant difference test and Dunken test with significance level set at 0.05.

RESULTS

Exposure to different doses was done at four points to identify the relationship between the dose and CDC25A protein expression changes. The presence of the CDC25A phosphatase in bone marrow cell lysates was evaluated. After Western blotting, the bands related to the CDC25A phosphatase were observed in irradiated mice (Figure 2). In addition, β-actin was used as internal control. At this stage, Image J software was used to convert the Western blot images into quantitative data by giving the color intensity and area of each band a numerical score. It should be noted that the numbers calculated by the Image J software are only figures that represent specific coordinates of the selected curves. In other words, these numbers do not represent the amount of proteins in each band based on milligrams or any other unit.
DISCUSSION
In recent years, significant improvements have been made in better identification of cell cycle and factors affecting it. While several factors affect the cell cycle, UV and ionizing radiation are among the factors that cause DNA damage. Based on severity of the damage, these factors may either cause cell cycle arrest to repair the damaged DNA or accelerate the cell cycle and cause cancer (1, 2). Meanwhile, the changes in the expression of some genes such as overexpression of proto-oncogenes interrupt the cell cycle. The proto-oncogene \textit{CDC25A} is highly regulated during the cell cycle because of its importance in determining the cell’s fate. Misregulation of the \textit{CDC25A} leads to accumulation of DNA damage and loss of genomic integrity (19). The \textit{CDC25A} phosphatase is destroyed in case of DNA damage replication arrest (13). The DNA damages are ignored and macromolecular damage is accelerated by misregulation of \textit{CDC25A} phosphatase function in checkpoints (8, 18). Bone marrow is more sensitive to ionizing radiationsince it contains cells with active cell cycle that are constantly dividing (19). In the present study, in vivo irradiation with different doses led to significant overexpression of \textit{CDC25A} phosphatase compared to the control, which could indicate cell cycle acceleration. \textit{CDC25A} is a cellular proto-oncogene gene and its activation in the early stages of tumor progression causes DNA replication stress. This can lead to malignancy because of induced DNA damage response (DDR) and selection of defective cells in the DDR (20). Consistent with the results of the present study, Ming-Yii Huang et al. demonstrated the overexpression of a large number of genes in colorectal cancer after radiotherapy. In the mentioned study, bioinformatics database analysis showed that 30 of these genes were involved in the DDR, immune response and complement pathways as well as the coagulation cascade. The \textit{CDC25A} was among the overexpressed genes in the colorectal cancer after radiation (21). However, the results of many studies differ from our results, which could be due to several reasons such as different target tissues selected (bone marrow in the present study), dosage, study conditions (in vivo or in vitro), mutations, etc. For example, study of Jodi Yanagida et al. on expression of skin cells showed that exposure of mice to UV radiation degrades \textit{CDC25A} phosphatase and leads to cell cycle arrest (22). Cell cycle arrest at the checkpoints enables the cell to repair DNA damage and reduce tumorigenesis. Moreover, some mutations affect the stability of the \textit{CDC25A} protein. Goloudina AR et al. reported that S75A mutation destroys \textit{CDC25A} in normal and stressed cells (23). It is suggested to investigate the tumorigenic and cell arrest capability of proliferating cells exposed to ionizing radiation in vitro, compared to control cells.

CONCLUSION
\textit{CDC25A} is an important proto-oncogene and its overexpression accelerates cell cycle and tumorigenesis. The results of this study show that the presence of ionizing radiation increases \textit{CDC25A} phosphatase expression. Moreover, there may be the possibility of cell cycle acceleration and tumorigenesis in people exposed to radiations.

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CONFLICT OF INTEREST
The authors declare no conflicts of interest regarding this manuscript.
REFERENCES