Principles of Radiation Protection in Radiotherapy

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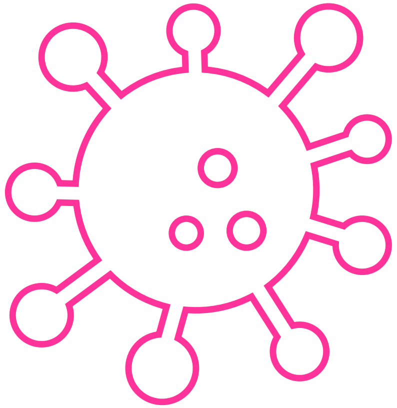
BASICS OF RADIOBIOLOGY

IRRADIATED CELLS



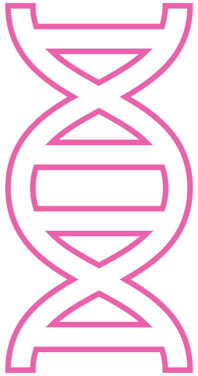
The biological damage due to radiation can be throughout direct ionizing damage, where the atoms of the target itself may be ionized or excited trough Coulomb interaction. This lead to a chain of physical and chemical interactions which cause biological damage. Damage can also be caused throughout indirect ionization. The radiation interacts with other molecules and atoms within the cell and produces free radicals. Radicals as H2O+ and OH are produced. These radicals can by diffusion within the cell damage the target cells and by this they can lead to biochemical changes.[1-2]

IRRADIATED CELLS

An irradiated cell can have several possible outcomes:[1-2]

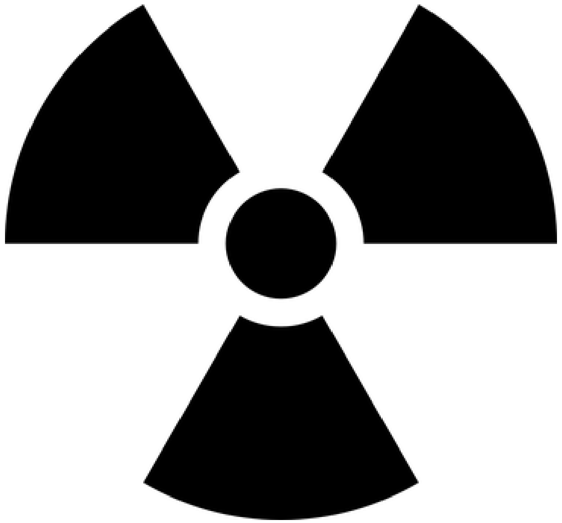
- The radiation can have no effect,[1-2]
- Division delay,[1-2]
- Apoptosis; the cell dies and divides into smaller bodies, which are taken up by neighbour cells.[1-2]
- Reproductive failure; the cell dies when attempting mitosis,[1-2]
- Genomic instability: a delay from reproductive failure by induced genomic instability,[1-2]
- Mutation; the cell survives and contains a mutation. The mutation can possible change the phenotype and possibly can cause carcinogenesis.[1-2]

DNA DAMAGE



DNA can be damaged by ionizing radiation in several ways. There can be double-stranded fractures, nitrogen base damage, cross-bindings and single-stranded fractures. The single-stranded fractures can be prepared because of the nitrogen base pare. When there is a single-stranded fracture, the damage will be recognised. The DNA will unwind itself locally and the dual strands will be incised. The syntheses will be repaired and the strands will ligate. These actions result in reparation of the DNA. Repair of DNA can lead to healthy prepare or to an incorrect repair. With an incorrect repair there is an incorrect amalgamation. This incorrect amalgamation repeats itself in the DNA division and it can cause a mutation. A double-stranded fracture lead to lethal damage because the origin of the nitrogen pair cannot be founded out.[1-2]

DETERMINISTIC EFFECTS



Deterministic effects of radiation are the tissue and organs effects and these effects are in the whole cell. The ionising radiation causes damage in the DNA which lead to cellular damage and this eventually causes cell death. This can be seen as acute damage, when the results are visible after days or weeks or as late damage when the effects occur after months or years. The deterministic effects are functional and morphological damage. This damage is seen in tissues after a threshold value is preceded. The given dose before preceding the threshold value is called the toleration dose. When the dose is within the toleration dose, no effects will be shown in the tissue. There is an correlation with the dose and the graduation of the effect. The effects of the radiation depends on the exposed dose, the exposed volume, the kind of radiation and the exposing time.[1-2]

DETERMINISTIC EFFECTS: ACUTE AND LATE

The acute reacting tissues are the fast dividing tissues. These tissues also repair themselves fast. These tissues include e.g. the epidermis, the intestinal epithelium and the mucosa in the mouth.[1-2]

The late reacting tissues are the slow dividing tissues. These tissues repair slower. These tissues include e.g. the dermis, the vessels, the nerves, the muscle fibres and the tissue of the heart, lungs and kidneys.[1-2]

The radiation effects:[1-2]

- Atrophy (decreasing of the volume of the tissue)
- Damage of the capillaries of the tissue
- Chronical inflammation of the organ
- Fibrosis (fibrous tissue formation)
- Sclerosis (tissue hardening)
- Necrose (tissue death)

The radiation effects in the body depend on the sensitivity of the exposed tissue and volume. [1-2]

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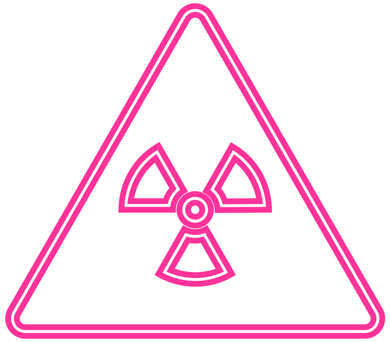
STOCHASTIC EFFECTS



Stochastics effects of radiation are the carcinogenic and genetic effects and they appear in the core of the cell. There is damage in the DNA of the cell. This damage is incorrectly repaired and causes a mutation in the division of the cell. This causes stochastic effects. The introduction of the effects are related by chance. There is no threshold value and there is no relation with the dose and the graduation of the effects. The chance that the effect will appear rises when the dose is rising. The dose effect relation is in general linear-quadratic. Many factors influence the chance that stochastic effects will appear, e.g. genetic, immunological, hormonal and viral factors.[1-2]

STOCHASTIC EFFECTS MODEL

The risk of developing stochastic effects are showed in two models of:

The Active Risico Projection Model (ARPM) is an absolute and dependable of the dose model. It is undependable of the age of the exposure and the natural frequency.[2]

The Multiplicative Risico Projection Model (MRPM) is dependable of the dose, age and the natural frequency. [2]

TUMOUR CONTROL PROBABILITY

The aim of radiation therapy is to deliver enough radiation in the tumour to destroy it without irradiating normal tissue to a dose that will lead to morbidity. The protection against radiation is important because of the harm of the radiation in patients. The tumour control should be greater than the damage in the healthy tissue. The greater the therapeutical ratio, the easier it is to achieve the radio therapeutical goal. [1-2]

TUMOUR CONTROL PROBABILITY

The TCP is under influence of the following factors:

- The toleration of the tumour
- The toleration of the healthy tissue
- The fraction schedules
- The physical and biological dose
- The sensitivity of the tumour visualised by the five R's (see next two slides)[1-2]

It is important to take these factors into account when making a treatment planning to treat the tumour most optimally and to save as much healthy tissue.[2]

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THE 5 R'S

The five R's are: radiosensitivity, repair, repopulation, redistribution and re-oxygenation.

1) Radiosensitivity**:** The radiation sensitivity of the tissue. The type and the quality of the radiation, the irradiated volume and the phase of the cell cycles influence the radiosensitivity of the tissue. The cell proliferation is defined into two time periods. These are the mitosis and the DNA synthesis phase. In general, the cells are the most sensitive in the mitosis and G2 phase and they are most resistance in the DNA synthesis phase.[1-2-3]

2) Repair: The repair of the sublethal DNA damage. There is a difference of repair of healthy tissue and the tissue of the tumour. Healthy tissue starts repairing after 2 to 4 hours and repairs faster than tumour tissue.[1-2-3]

3) Repopulation**:** The replacement of the dead cells by proliferation. The repair of the healthy tissues and the tumour tissue. The repair of the tumour tissue is an import reason of recurrence. It is important to take the time interval between the fractions into account. [1-2-3]

4) Redistribution: The synchronization of the survived cells. The sensitivity depends on the survival of the radiation resistance of the phase.[1-2-3]

5) Re-oxygenation**:** The tumour cells can survive the radiation therapy because of hypoxia, a decrease in the oxygen supply. Radiation therapy can increase the oxygenation. For the treatment there can be oxygen added in the tissues to make the treatment more effective.[1-2-3]

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BASICS OF RADIATION PROTECTION

RADIATION PROTECTION

The aim of radiation protection is to prevent the healthy tissue of damage and the deterministic and stochastic effects. Aim is also to prevent the side effects which are inevitable. The side effects can differentiate in grade. The aim of radiation protection in radiation therapy is to keep the grade of the side effects as low as possible.[2,4]

Every exposure for the patient has to be justified to avoid unnecessary exposures procedures. In the justification it is required that the introduction of a new source of radiation or any actions to reduce radiation have to have an overall benefit. The actions have to have a balance in the overall benefit and risk. The justification is carried out by a consultation between the referring practitioner and the responsible preforming practitioner. The health authority applies the justification of new technologies and techniques as they evolve.[2,4]

When the examination is justified, the procedure should be optimised such that the exposure of the patient is managed to achieve the medical objective that it lead to the required medical outcome.[2,4]

RADIATION PROTECTION STRATEGIES

Radiation exposure can be limited due by the principles of **time, distancing and shielding**.

Time
The shorter the exposure time, the lower the dose. When a worker or a member of the public is in the treatment room, there is no exposure.

Distance
By keeping distance from the source, the energy of the of the radiation decreases by the inverse square law.

Shielding
The treatment room is designed to protect for high energetic photons radiation. The walls contain high density materials and they don't pass more dose than the law allows.[5]

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PREGNANCY

When the women who undergoes a treatment is pregnant, the scattered radiation can irradiate the fetus. Irradiation of the fetus can cause malformation of organs in the 3th to 8th week in the pregnancy, a reduction of the IQ or mental retardation in 8th to 15th week into the pregnancy and in lower grades into 16th to 25th week of the pregnancy.[6]

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DOSE LIMITATION

There is no hard dose limit for the patient. Radiation is used with the aim to damage the tumour tissue. The organs at risk (OAR) have a toleration dose for deterministic effects, which are the side effects of the therapy.

Strategies of radiation protection aims to reduce unnecessary radiation exposure with a goal to minimise the harmful effects of radiation in the heathy tissues. The dose in the OAR should be by the as low as reasonable achievable (ALARA) principle to decrease the chance of developing stochastic effects.[7]

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