Second Workshop Radiotherapy & Mathematics

Title: Biological effects of Radiation. What it does? and how to follow up?

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Summary:

What it does?

When radiation interacts with target atoms, energy is deposited resulting in ionization or excitation. The absorption of energy from ionizing radiation produces damage to molecules by **direct** and **indirect** actions.

For direct action, damage occurs as a result of ionization of atoms on key molecules in the biologic system. This causes inactivation or functional alteration of the molecule. Indirect action involves the production of reactive free radicals whose toxic damage on the key molecule results in a biologic effect.

The effects of radiation on the cell include interference with cell division, damage to chromosomes, damage to genes (mutations), neoplastic transformation, and cell death. We tend to think of biological effects of radiation in terms of their effect on living cells. For low levels of radiation exposure, the biological effects are so small they may not be detected. The body has repair mechanisms against damage induced by radiation as well as by chemical carcinogens. Consequently, biological effects of radiation on living cells may result in four outcomes: (1) **Cells are undamaged by the dose**: Ionization may form chemically active substances which in some cases alter the structure of the cells. These alterations may be the same as those changes that occur naturally in the cell and may have no negative effect. (2) **Cells are damaged, repair the damage and operate normally**: Some ionizing events produce substances not normally found in the cell. These can lead to a breakdown of the cell structure and its components. Cells can repair the damage if it is limited. Even damage to the chromosomes is usually repaired. Many thousands of chromosome aberrations (changes) occur constantly in our bodies. We have effective mechanisms to repair these changes. (3) **Cells are damaged, repair the damage and operate abnormally**: If a damaged cell needs to perform a function before it has had time to repair itself, it will either be unable to perform the repair function or perform the function incorrectly or incompletely. The result may be cells that cannot perform their normal functions or that now are damaging to other cells. These altered cells may be unable to reproduce themselves or may reproduce at an uncontrolled rate. Such cells can be the underlying causes of cancers. (4) **Cells die as a result of the damage**: If a cell is extensively damaged by radiation, or damaged in such a way that reproduction is affected, the cell may die. Radiation damage to cells may depend on how sensitive the cells are to radiation.

How to follow up?

The effect of radiation on biological systems can be followed by imaging techniques. Medical imaging is the technique and process used to create images of the human body (or parts and function thereof) for clinical purposes. The multiple and numerous potentialities of this field are applicable to the diagnosis of diseases such as cancer, and neurological and cardiovascular diseases.

There are two main imaging modalities: **anatomical** (give us information about the tissue/organ structure) and **functional** (give us information on the metabolism underlying that structure.) Some of these methodologies are:

Diagnostic Radiology: X-rays penetrate most biological tissues with little attenuation, and thus provide a comparatively simple means to produce shadow, or projection, images of the human body.

Computed Tomography: conventional radiography provides no depth information. In contrast, x-ray computed tomography (CT) imaging produces thin 2D sections of the body with sub-millimetre spatial resolution and good discrimination between tissues.

Ultrasound: High frequency pulses of acoustic energy are emitted and measurement of time delay and intensity of the reflected pulses (echoes) were obtained, an image indicating tissue interfaces can be reconstructed.

Magnetic Resonance Imaging: patient is placed inside a strong magnetic field to obtain images as a function of proton spin density and relaxation times (or spectra of 31P and 1H in NMR spectroscopy). Radioisotope Imaging: Radioisotope tagged compounds in tracer quantities are injected into the patient's body where they decay and produce detectable γ-photons.

Single Photon Emission Computed Tomography (SPECT): a single g-ray is emitted per nuclear decay. A gamma camera, fitted with a parallel-hole collimator, rotates around the patient and records 1D projections of the radioactivity.

Positron Emission Tomography (PET) is based on Annihilation Coincidence Detection. Decay of a radionuclide produces a positron which, after a short travel, collides with an electron and annihilates, generating two antiparallel γ-rays at 511 keV each.

OPTICAL imaging: In-vivo fluorescence and bioluminescence imaging plays a crucial role in interrogating biological systems, particularly, rodent models for human diseases. Majority of the systems generate images of the integrated light distribution emitted from the surface, severely compromising the ability to perform quantify and accurately localize the signals due to the strong dependence of the tissue optical properties on depth.