X – RAY DEPARTMENT

Lecture 9. **د. ســناء القصــاب**

Introduction

It is a well-publicized fact that ionizing radiation is harmful to biologic tissues. In sufficient amounts and intensities, it may cause Irreparable tissue damage, cancer, and even death of an organism. Patients will undoubtedly be aware of this fact and may express concern about having radiographs taken. It is the responsibility of the clinician to inform the patient of the risks involved with, and yet the benefits derived from, exposure to diagnostic levels of x-radiation. Unfortunately, this is not an easy task, because the effects of exposure to low levels of radiation are not known for certain.

THE EFFECT OF RADIATION ON BIOLOGIC MOLECULES

Direct and Indirect Effects

If the energy in an x-ray beam initially interacts with a biologic molecule to produce ionization in that molecule, that event is said to be a *direct effect* of the radiation. For example, if a DNA molecule is hit by an x-ray photon, the direct ionizing event may break the DNA strand or cause a change in base sequence, potentially altering the code the molecule is carrying. This type of interaction is, however, less likely to occur than an *indirect effect* of radiation, in which a different molecule, for example water, is ionized and then interacts further with a particular biologic molecule.

Biologic tissues are composed primarily of water, and irradiation of water produces *radiolysis.* Water dissociates into two ions:

hi>0 ^ HOI-^ + e-

Following the dissociation, the water ions may reassociate into a complete water molecule or may promote other reactions:

HOI^ + e- + another HgO ->
HOH- + HOI-T

The HC and HOH- ions are relatively unstable and may further dissociate:

HOI-T -. 1-T + OH*
HOH- -^ OH- + H*

The OH* and H' are *free radicals.* A free radical is a neutral (uncharged) molecule with a single, unpaired electron in its outermost orbital shell. Free radicals are highly reactive and unstable and exist for only about 10^{-5} second. They may stabilize themselves by pairing their unpaired electrons with other molecules' orbital electrons, by transferring their extra electrons to other molecules, or by "stealing" electrons from a neighboring organic molecule (RH), which, in turn, becomes a free radical:

rh + H* -^ R* + hi,
RH + OH* -> R* + HgO

The newly created free radicals (R") also seek to stabilize themselves by reacting with other molecules. In addition, the H* and OH* radicals may react as follows:

OH* + OH* -^ H;A
H* + 0, ^ HO/
HOg* + HOa* — ha + Og

Hydrogen peroxide (HgOg) and the hydroperoxyl radical (HOg*) are toxic to biologic tissues and may cause damage via the in direct route.

Radiation damage in biologic molecules occurs almost exclusively by indirect effects, not by direct ionization, although both do occur. *No matter by which effect:, damage to* a biologic molecule may

result in the inactivation of that molecule or the production of highly reactive and potentially damaging molecules.

Radiation Effects on Cells

The cell, or basic structural unit of all living organisms, is composed of a central nucleus and surrounding cytoplasm. Ionizing radiation may affect the nucleus, the cytoplasm, or the entire cell. The cell nucleus is more sensitive to radiation than the cytoplasm. Damage to the nucleus affects the chromosomes containing DNA and results in disruption of cell division. which in turn may lead to disruption of cell function or cell death.

Not all cells respond to radiation in the same manner. A cell that is sensitive to radiation is termed radiosensitive; one that is resistant is termed radioresistant**.** The response of a cell to radiation exposure is determined by the following:

• Mitotic activity: Cells that divide frequently or undergo many divisions over time arc more sensitive to radiation.

• Cell metabolism: Cells that have a higher metabolism are more sensitive to radiation.

Cells that are radiosensitive include blood cells, immature reproductive cells, and young bone cells. The cell that is most sensitive to radiation is the small
lymphocyte. Radioresistant cells include cells of bone, muscle, and nerve.

Radiation Effects on Tissues and Organs

Cells are organized into larger functioning units termed tissues and organs. Just as cells van' in their sensitivity to radiation, so do tissues and organs. Radiosensitive organs are composed of radiosensitive cells and include Iymphoid tissues, bone marrow, testes, and intestines.

Examples of radio resistant tissues include the salivary glands, kidney, and liver.

In dentistry, some tissues and organs are designated as critical because they are exposed to more radiation than others during radiographic procedures. A critical organ is an organ that if damaged diminishes the quality of a person's life. Critical organs exposed during denial radiographic procedures in the head and neck region include:

- skin
- thyroid gland
- lens of the eye
- bone marrow

TABLE 2–1. Relative Radiosensitivities of Adult Cell Types

Level of Sensitivity	Cell Type
Highest	Erythroblasts and other stem cells of hematopoietic tissue
	Intestinal crypts of Lieberkühn
	Basal epidermal and gastric gland cells
	Spermatogonia
	Granulosa cells of ovarian follicles
	Lymphocytes
High	Spermatocytes
	Ovocytes
Intermediate	Endothelium
	Fibroblasts
	Osteoblasts
	Salivary gland acinar cells
Low	Salivary gland duct cells
	Liver
	Kidney
	Pancreas
	Adrenal gland
	Thyroid gland
	Pituitary gland
Lowest	Neurons
	Muscle cells
	Erythrocytes
	Spermatozoa

TABLE 2–2. Relative Radiosensitivities of Tissues and Organs

Relative Sensitivity	Tissue/Organ
Highest	Lymphoid tissue
	Bone marrow
	Gonads
	Intestinal epithelium
High	Skin
	Cornea
	Gastrointestinal tract, including oral mucosa
Intermediate	Connective tissue
	Fine vasculature
	Growing cartilage and bone
Low	Mature cartilage and bone
	Kidney
	Liver
	Adult thyroid gland
	Salivary gland
Lowest	Muscle
	Nerves
	Central nervous system

Effects OF radiotherapy ON oraltissues

Radiation doses used in the treatment of malignant neoplasms in the head and neck area often reach 40 to 50 Gy. Doses as high as these produce significant localized, early effects on oral tissues. One of the first reactions to appear is an erythema and edema of the oral mucosa, or *radiation mucositis.*

The earliest signs may appear with doses as low as 1 to 3 Gy, which may be only 1 or 2 days' therapy. Ulceration and desquamation often follow. After about 2 weeks of radiotherapy, patients may encounter difficulty in eating or speaking because of the discomfort that is inherent in mucositis.

Interruption of therapy may be necessary until the patient's condition is stabilized.

Oral mucosa in such a deteriorated condition is more susceptible to an overgrowth of oral microorganisms, and candidiasis and secondary infection can be serious problems in radiotherapy (RT) patients. The signs and symptoms of mucositis wane after therapy has been completed.

Patients may experience a loss of taste acuity during and following radiotherapy. A 50% reduction in the perception of bitterness and acidity may occur with doses of approximately 2.5 to 4 Gy, and a total loss of taste may coincide with an accumulated dose of 30 Gy. Although some taste loss is related to mucositis and a decrease in salivary flow, there appears to be a direct effect of radiation on the taste buds. Partial or total restoration of taste may occur in 2 to 4 months following radiotherapy.

Xerostomia is a significant result of irradiation of salivary gland tissue. Following a dose as low as 1 to 2 Gy, patients may report a sensation of dryness in the mouth, and the glands may swell and become painful.

More radiation leads to further reductions in the volume of saliva produced, and the viscosity increases while the pH and levels of salivary immunoglobulins decrease. Serous cells appear to be more radiosensitive than mucous cells. It is unclear whether the damage to the salivary glands is a direct result of epithelial cell injury or whether it stems from vascular, neural, or other metabolic injury.

The increase in the viscosity of the saliva and the decrease in flow and pH affect the composition of the population of oral microorganisms. Cariogenic organisms are favored over the noncariogenic, and this shift, coupled with the salivary changes, predisposes the patient to rapidly progressing caries. Smooth surfaces and areas of reduced protection, such as exposed root surfaces and wear facets, are susceptible to the rapidly destructive process. The term *radiation caries* is sometimes applied to the process, but this is a misnomer. The radiation *itself* has no effect on erupted teeth.

Xerostomia, the accompanying loss of lubrication, buffering, and antibacterial capacities of the saliva, and the shift in oral flora populations are causes of the caries. For example, a xerostomic environment favors *Streptococcus mutans* and *Lactobacillus* species, organisms that are highly implicated in caries production. Impeccable oral hygiene and daily applications of topical fluoride help prevent devastation of the dentition.

Bone exposed to therapeutic doses of radiation loses its capacity for regeneration or response to injury. The lost capacity is thought to be the result of damage to the vasculature nourishing the bone and a decrease in the number of viable osteocytes and osteoblasts. The compromise in the vasculature is particularly problematic in the mandible, because the primary vascular supply stems from the inferior alveolar vessels, and there is little chance for collateral circulation following radiotherapy. The condition is less likely to occur in the maxilla, because it has an anastomosing blood supply and less dense bone than is present in the mandible; therefore, radiation injuries are more common in the mandible than in the maxilla.

Should the irradiated bone be subject to invasion by oral microflora, an acute or chronic osteomyelitis often ensues. Treatment of such an infection is difficult due to the compromised vascular supply. Doses over 50 to 60 Gy may result in necrosis of the bone; this *osteoradionecrosis* remains a permanent problem for the patient after radiotherapy has ceased. Trauma or insult may promote

osteomyelitis, and necrotic tissue may sequestrate spontaneously. Treatment may consist of intensive antibiotic therapy, hyperbaric oxygenation, or surgical resection. The patient may remain asymptomatic, or symptoms of pain, swelling, and drainage may arise shortly after therapy or as long as several years following therapy.

THE EFFECT OF NONIONIZING DIAGNOSTIC RADIATIONS ON BIOLOGIC TISSUE

Ultrasound

The use of ultrasound is increasing in popularity for diagnostic imaging. It appears to be a relatively safe technique when compared to those methods employing ionizing radiation. The research in the area of safety is not advanced enough to provide more than tentative conclusions, but there has not been a single known instance of an adverse effect from clinical ultrasound in humans. However, the bioeffects of ultrasound have been shown in vitro and animal experiments. Power intensities greater than those used for diagnosis may promote free radical formation, elevate the temperature of a biologic tissue, produce cavitation, or create viscous stress.

' *Temperature elevation* may lead to structural changes in macromolecules or membranes, or change the rate at which biochemical reactions occur. *Captation* is the process by which very small gas bubbles, or cavities, are formed in the cells. These may lead to disruption of molecular bonds or the production of free radicals. *Viscous stress is* produced when the viscosity differs on each side of a membrane and small-scale fluid movements occur. Such microstreaming may disrupt cell membranes. There has been no comprehensive, well-controlled, large-scale human study of the possibility of subtle, long-term, or cumulative effects of 'exposure to diagnostic ultrasound. Epidemiologic studies over the past 25 years have not shown any evidence of harmful effects in humans. The current absence of proof does not, however, preclude its cautious use only when benefit is anticipated.

Magnetic Resonance

There is little information available concerning the human response to magnetic resonance imaging (MRI). Research on other living tissues has shown that extreme levels may have some effect. These effects stem from exposure to a strong static magnetic field, a varying magnetic field, and radiofrequencies. Exposure to a very strong static magnetic field may result in alterations in membrane permeability, enzyme kinetics, neural conduction, and muscle function.

Varying magnetic fields may induce a current density in tissue that may influence bone healing and cardiac muscle function.

The principal effect of a radiofrequency field on biologic tissue is heat production. Diagnostic MRI has been linked with temperature elevation in corneal tissue, but it does not appear to pose a biologic hazard to humans.

As with ultrasound, there is no scientific evidence one way or the other concerning the safety of MRI. Although it is very likely that the benefits far outweigh the risks, the technique should be used with due caution and only when a benefit to the patient is expected.

SUMMARY

- All ionizing radiation is harmful and produces biologic changes in living tissue.
- Radiation injury occurs as a result of ionization or free radical formation.

• A dose-response curve is used to demonstrate the response (damage) of tissues to the dose (amount) of radiation received.
• A threshold dose for damage does not exist and the response of tissues is directly proportional to the dose received.
• Radiation injury follows a sequence of events: latent period. period of injury, and period of recover).
• Radiation injury is affected by total dose, dose rate, amount of tissue irradiated, cell sensitivity, and age.
• Short-term radiation effects occur when large amounts of radiation are absorbed in a short period of lime; long-term absorbed over a long time period.
• Radiation eifects are classified as somatic (seen in the person irradiated or genetic (passed on to future generations).
• Cellular response to radiation depends on mitotic activity, cell differentiation, and cell metabolism.
• Radiosensitive cells include blood cells, immature reproductive cells, young bone cells, and epithelial cells. Radio resisiam cells include the cells of bones, muscle, and nerve.
•Exposure is the measurement of loncaiion in air produced by x-rays, the units for exposure are the roenigen (R) and coulombs per kilogram (C/kg).
• Dose is the amount 'of energy absorbed by a tissue; the units for dose are the radiation absorbed dose (rad) and the gray (GyV
• Dose equivalent measurement is used to compare the biologic effects of different types of radiation; the units for dose equivalent are the roentgen equivalent (in) man (rem) and the sieven (;Sv).
• The risks of radiation exposure involved in dental radiography are not significantly greater than other everyday risks in life.
• The amount of exposure a patient receives from dental radiographs depends on the film speed, collimation, technique, and exposure factors used.
• Dental radiographs should be prescribed only for a patient when the benefit of disease detection outweighs the risk of damage from x-radiation.

Radiation protection

• Prior to x-ray exposure, the- proper prescribing of dental radiographs and the use of proper equipment can minimize the amount of radiation that a patient receives.
• Radiographs must be prescribed by the dentist based on
• In the x-ray lubehead a collimator (lead plate with a hole in the middle) is used to restrict the size and shape of the
• The P1D is used to direct the x-ray beam; the rectangular PID is most effective in reducing patient exposure to x-rays.
• During x-ray exposure, a thyroid collar, a lead apron, fast film, and film-holding devices can be used to protect the patient from excess exposure to radiation. Proper selection of exposure factors and good technique can also be used to protect the patient.
• After x-ray exposure, careful film handling and film processing techniques are critical for the production of diagnostic radiographs.
• During x-ray exposure, the dental radiographer must at proper positioning and shielding.
• The denial radiographer must *never* hold a film or the lubehead in place for a patient during x-ray exposure

Equipment and personnel.

• Federal and state legislation has been established that protects the patient, the operator, and the general public from radiation hazards.

• Exposure limits have been established for the general pub permissible dose (‚MPD) for persons who work with radiation (e.g., dental radiographers) is 5.0 rem/vear (0.05 Sv/vear\ the MPD for persons who do not work with
radiation is 0.1 rem/year (0.001 Sv/year).
• ALARA *(as low as* reasonably achievable) is a concept that slates that all exposure to radiation must be kept to a
• The denial radiographer must be prepared to explain how