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 **PAPER: Therapeutic Radiology**

**Q.NO.1: What are the side effects of therapeutic radiology on the human body?**

**Ans:**

 **Side effects:**

* Radiation therapy is in itself painless.
* Many low-dose palliative treatments (for example, radiation therapy to bony metastases) cause minimal or no side effects, although short-term pain flare-up can be experienced in the days following treatment due to edema compressing nerves in the treated area.
* Higher doses can cause varying side effects during treatment (acute side effects), in the months or years following treatment (long-term side effects), or after re-treatment (cumulative side effects).
* The nature, severity, and longevity of side effects depends on the organs that receive the radiation, the treatment itself (type of radiation, dose, fractionation, concurrent chemotherapy), and the patient.
* Most side effects are predictable and expected.
* Side effects from radiation are usually limited to the area of the patient's body that is under treatment. Modern radiation therapy aims to reduce side effects to a minimum and to help the patient understand and deal with side effects that are unavoidable.
* The main side effects reported are fatigue and skin irritation, like a mild to moderate sun burn. The fatigue often sets in during the middle of a course of treatment and can last for weeks after treatment ends. The irritated skin will heal, but may not be as elastic as it was before.

**Acute side effects:**

**Nausea and vomiting**

This is not a general side effect of radiation therapy, and mechanistically is associated only with treatment of the stomach or abdomen (which commonly react a few hours after treatment), or with radiation therapy to certain nausing-producing structures in the head during treatment of certain head and neck tumors, most commonly the vestibules of the inner ears.[8] As with any distressing treatment, some patients vomit immediately during radiotherapy, or even in anticipation of it, but this is considered a psychological response. Nausea for any reason can be treated with antiemetics.

**Damage to the epithelial surfaces:**

Epithelial surfaces may sustain damage from radiation therapy. Depending on the area being treated, this may include the skin, oral mucosa, pharyngeal, bowel mucosa and ureter. The rates of onset of damage and recovery from it depend upon the turnover rate of epithelial cells. Typically the skin starts to become pink and sore several weeks into treatment. The reaction may become more severe during the treatment and for up to about one week following the end of radiation therapy, and the skin may break down. Although this moist desquamation is uncomfortable, recovery is usually quick. Skin reactions tend to be worse in areas where there are natural folds in the skin, such as underneath the female breast, behind the ear, and in the groin.

**Mouth, throat and stomach sores:**

If the head and neck area is treated, temporary soreness and ulceration commonly occur in the mouth and throat.[11] If severe, this can affect swallowing, and the patient may need painkillers and nutritional support/food supplements. The esophagus can also become sore if it is treated directly, or if, as commonly occurs, it receives a dose of collateral radiation during treatment of lung cancer. When treating liver malignancies and metastases, it is possible for collateral radiation to cause gastric, stomach or duodenal ulcers. This collateral radiation is commonly caused by non-targeted delivery (reflux) of the radioactive agents being infused.[14] Methods, techniques and devices are available to lower the occurrence of this type of adverse side effect.

**Intestinal discomfort:**

The lower bowel may be treated directly with radiation (treatment of rectal or anal cancer) or be exposed by radiation therapy to other pelvic structures (prostate, bladder, female genital tract). Typical symptoms are soreness, diarrhea, and nausea.

**Swelling:**

As part of the general inflammation that occurs, swelling of soft tissues may cause problems during radiation therapy. This is a concern during treatment of brain tumors and brain metastases, especially where there is pre-existing raised intracranial pressure or where the tumor is causing near-total obstruction of a lumen (e.g., trachea or main bronchus). Surgical intervention may be considered prior to treatment with radiation. If surgery is deemed unnecessary or inappropriate, the patient may receive steroids during radiation therapy to reduce swelling.

**Infertility:**

The gonads (ovaries and testicles) are very sensitive to radiation. They may be unable to produce gametes following direct exposure to most normal treatment doses of radiation. Treatment planning for all body sites is designed to minimize, if not completely exclude dose to the gonads if they are not the primary area of treatment. Infertility can be efficiently avoided by sparing at least one gonad from radiation.[16]

**Late side effects:**

Late side effects occur months to years after treatment and are generally limited to the area that has been treated. They are often due to damage of blood vessels and connective tissue cells. Many late effects are reduced by fractionating treatment into smaller parts.

**Fibrosis:**

Tissues which have been irradiated tend to become less elastic over time due to a diffuse scarring process.

**Epilation:**

Epilation (hair loss) may occur on any hair bearing skin with doses above 1Gy. It only occurs within the radiation field/s. Hair loss may be permanent with a single dose of 10Gy, but if the dose is fractionated permanent hair loss may not occur until dose exceeds 45Gy.

**Dryness:**

The salivary glands and tear glands have a radiation tolerance of about 30 Gy in 2 Gy fractions, a dose which is exceeded by most radical head and neck cancer treatments. Dry mouth (xerostomia) and dry eyes (exophthalmia) can become irritating long-term problems and severely reduce the patient's quality of life. Similarly, sweat glands in treated skin (such as the armpit) tend to stop working, and the naturally moist vaginal mucosa is often dry following pelvic irradiation.

**Lymphedema:**

Lymphedema, a condition of localized fluid retention and tissue swelling, can result from damage to the lymphatic system sustained during radiation therapy. It is the most commonly reported complication in breast radiation therapy patients who receive adjuvant axillary radiotherapy following surgery to clear the axillary lymph nodes.

**Cancer:**

Radiation is a potential cause of cancer, and secondary malignancies are seen in a very small minority of patients – usually less than 1/1000. It usually occurs 20 – 30 years following treatment, although some hematological malignancies may develop within 5 – 10 years. In the vast majority of cases, this risk is greatly outweighed by the reduction in risk conferred by treating the primary cancer. The cancer occurs within the treated area of the patient.

**Heart disease:**

Radiation has potentially excess risk of death from heart disease seen after some past breast cancer RT regimens.

**Cognitive decline:**

In cases of radiation applied to the head radiation therapy may cause cognitive decline. Cognitive decline was especially apparent in young children, between the ages of 5 to 11. Studies found, for example, that the IQ of 5 year old children declined each year after treatment by several IQ points.

**Radiation proctitis:**

This can involve long-term effects on the rectum including bleeding, diarrhea and urgency and is associated with radiation therapy to pelvic organs. Pelvic radiation therapy can also cause radiation cystitis when the bladder is affected

**Cumulative side effects:**

Cumulative effects from this process should not be confused with long-term effects—when short-term effects have disappeared and long-term effects are subclinical, irradiation can still be problematic.

**Effects on reproduction:**

During the first two weeks after fertilization, radiation therapy is lethal but not erotogenic. High doses of radiation during pregnancy induce anomalies, impaired growth and intellectual disability, and there may be an increased risk of childhood leukemia and other tumors in the offspring.

In males previously having undergone radiotherapy, there appears to be no increase in genetic defects or congenital malformations in their children conceived after therapy. However, the use of assisted reproductive technologies and micromanipulation techniques might increase this risk.

**Effects on pituitary system:**

Hypopituitarism commonly develops after radiation therapy for seller and parasellar neoplasms, extrasolar brain tumors, head and neck tumors, and following whole body irradiation for systemic malignancies. Radiation-induced hypopituitarism mainly affects growth hormone and gonadal hormones. In contrast, adrenocorticotrophic hormone (ACTH) and thyroid stimulating hormone (TSH) deficiencies are the least common among people with radiation-induced hypopituitarism. Changes in prolactin-secretion is usually mild, and vasopressin deficiency appears to be very rare as a consequence of radiation.

**Q.no.2: What do you know about linear accelerator? How the machine work?**

**Ans:**

**Linear accelerators**

High-energy radiation is delivered to tumors by means of a linear accelerator.

A beam of electrons is generated and accelerated through a waveguide that

Increases their energy to the keV to MeV range. These electrons strike a tungsten

Target and produce x-rays.

X-rays generated in the 10–30-keV range are known as grenz rays, whereas

The energy range for superficial units is about 30–125 keV. Orthovoltage units

generate x-rays from 125–500 keV.

1. **Orthovoltage units**

These continue to be used today to treat superficial lesions; in

Fact, they were practically the only machines treating skin lesions before the

Recent emergence of electron therapy. The maximum dose from any of these

Low-energy units is found on the surface of patients; thus, skin becomes the

Dose-limiting structure when treating patients at these energies. The depth at

Which the dose is 50% of the maximum is about 7 cm. Table 1 lists the physical

Characteristics of several relevant x-ray energies.

1. **Megavoltage units**

 The megavoltage linear accelerator has been the standard radiotherapy equipment for the past 20-30 years. Its production of x-rays is identical to that of lower-energy machines. However, the energy range of megavoltage units is quite broad—from 4 to 20 MeV. The depth of the maximum dose in this energy range is 1.5-3.5 cm. The dose to the skin is about 30%-40% of the maximum dose.

Most megavoltage units today also have electron-beam capabilities, usually in

the energy range of about 5-20 MeV. In order to produce an electron beam,

the tungsten target is moved away from the path of the beam. The original

electron beam that was aimed at the tungsten target is now the electron beam

used for treatment. Unlike that of photons, the electron skin dose is quite high,

about 80%-95% of the maximum dose. A rule of thumb regarding the depth of

penetration of electrons is that 80% of the dose is delivered at a depth (in cm)

corresponding to one-third of the electron energy (in MeV). Thus, a 12-MeV

beam will deliver 80% of the dose at a depth of 4 cm.

***Altering beam intensity and field size:***

When measurements are made at the point just past the target, the beam is more intense in the center than at the edges. Optimal treatment planning is obtained with a relatively constant intensity across the width of the beam. This process is accomplished by placing a flattening filter below the target.

In order for the radiation beam to conform to a certain size, high atomic number

collimators are installed in the machine. They can vary the field size from

4 × 4 cm to 40 × 40 cm at a distance of 100 cm from the target, which is the

distance at which most treatments are performed.

If it is decided that a beam should be more intense on one side than the other,

high atomic number filters, known as wedges, are placed in the beam. These

filters can shift the dose distribution surrounding the tumor by 15º-60º. Wedges

can also be used to optimize the dose distribution if the treatment surface is

curved or irregular.

***Shielding normal tissue***:

Once the collimators have been opened to the desired field size that encompasses the tumor, the physician may decide to block out some normal tissue that remains in the treatment field. This is accomplished by placing blocks (or alloy), constructed of a combination of bismuth, tin, cadmium, and lead, in the path of the beam. In this way, normal tissues are shielded, and the dose can be delivered to the tumor at a higher level than if the normal structures were in the field. These individually constructed blocks are used in both x-ray and electron treatments. A more modern technique involves multileaf collimators mounted inside the gantry. They provide computerized, customized blocking instead of having to construct a new block for each field. (See “Intensity-modulated radiation therapy.”)

**Works of machine:**

* Radiation therapy works by damaging the DNA of cancerous cells.
* This DNA damage is caused by one of two types of energy, photon or charged particle.
* This damage is either direct or indirect ionization of the atoms which make up the DNA chain.
* Indirect ionization happens as a result of the ionization of water, forming free radicals, notably hydroxyl radicals, which then damage the DNA.
* In photon therapy, most of the radiation effect is through free radicals. Cells have mechanisms for repairing single-strand DNA damage and double-stranded DNA damage.
* However, double-stranded DNA breaks are much more difficult to repair, and can lead to dramatic chromosomal abnormalities and genetic deletions.
* Targeting double-stranded breaks increases the probability that cells will undergo cell death.
* Cancer cells are generally less differentiated and more stem cell-like; they reproduce more than most healthy differentiated cells, and have a diminished ability to repair sub-lethal damage.
* Single-strand DNA damage is then passed on through cell division; damage to the cancer cells' DNA accumulates, causing them to die or reproduce more slowly.
* One of the major limitations of photon radiation therapy is that the cells of solid tumors become deficient in oxygen.
* Solid tumors can outgrow their blood supply, causing a low-oxygen state known as hypoxia.
* Oxygen is a potent radio sensitizer, increasing the effectiveness of a given dose of radiation by forming DNA-damaging free radicals.
* Tumor cells in a hypoxic environment may be as much as 2 to 3 times more resistant to radiation damage than those in a normal oxygen environment.
* Much research has been devoted to overcoming hypoxia including the use of high pressure oxygen tanks, hyperthermia therapy (heat therapy which dilates blood vessels to the tumor site), blood substitutes that carry increased oxygen, hypoxic cell radio sensitizer drugs such as misonidazole and metronidazole, and hypoxic cytotoxins (tissue poisons), such as tirapazamine.
* Newer research approaches are currently being studied, including preclinical and clinical investigations into the use of an oxygen diffusion-enhancing compound such as trans sodium crocetinate (TSC) as a radio sensitizer.
* Charged particles such as protons and boron, carbon, and neon ions can cause direct damage to cancer cell DNA through high-LET (linear energy transfer) and have an antitumor effect independent of tumor oxygen supply because these particles act mostly via direct energy transfer usually causing double-stranded DNA breaks.
* Due to their relatively large mass, protons and other charged particles have little lateral side scatter in the tissue—the beam does not broaden much, stays focused on the tumor shape, and delivers small dose side-effects to surrounding tissue.
* They also more precisely target the tumor using the Bragg peak effect. See proton therapy for a good example of the different effects of intensity-modulated radiation therapy (IMRT) vs. charged particle therapy.
* This procedure reduces damage to healthy tissue between the charged particle radiation source and the tumor and sets a finite range for tissue damage after the tumor has been reached.
* In contrast, IMRT's use of uncharged particles causes its energy to damage healthy cells when it exits the body.
* This exiting damage is not therapeutic, can increase treatment side effects, and increases the probability of secondary cancer induction.
* This difference is very important in cases where the close proximity of other organs makes any stray ionization very damaging (example: head and neck cancers). This x-ray exposure is especially bad for children, due to their growing bodies, and they have a 30% chance of a second malignancy after 5 years post initial RT.

 **Dose:**

* The amount of radiation used in photon radiation therapy is measured in gray (Gy), and varies depending on the type and stage of cancer being treated.
* For curative cases, the typical dose for a solid epithelial tumor ranges from 60 to 80 Gy, while lymphomas are treated with 20 to 40 Gy.
* Preventive (adjuvant) doses are typically around 45–60 Gy in 1.8–2 Gy fractions (for breast, head, and neck cancers.) Many other factors are considered by radiation oncologists when selecting a dose, including whether the patient is receiving chemotherapy, patient comorbidities, whether radiation therapy is being administered before or after surgery, and the degree of success of surgery.
* Delivery parameters of a prescribed dose are determined during treatment planning (part of dissymmetry).
* Treatment planning is generally performed on dedicated computers using specialized treatment planning software.
* Depending on the radiation delivery method, several angles or sources may be used to sum to the total necessary dose.
* The planner will try to design a plan that delivers a uniform prescription dose to the tumor and minimizes dose to surrounding healthy tissues.
* In radiation therapy, three-dimensional dose distributions are often evaluated using the dissymmetry technique known as gel dissymmetry.

 **Fractionation:**

* (This section only applies to photon RT although other types of radiation therapy may be fractionated).
* The total dose is fractionated (spread out over time) for several important reasons.
* Fractionation allows normal cells time to recover, while tumor cells are generally less efficient in repair between fractions.
* Fractionation also allows tumor cells that were in a relatively radio-resistant phase of the cell cycle during one treatment to cycle into a sensitive phase of the cycle before the next fraction is given. Similarly, tumor cells that were chronically or acutely hypoxic (and therefore more radio resistant) may reoxygenate between fractions, improving the tumor cell kill.
* Fractionation regimens are individualized between different radiation therapy centers and even between individual doctors. In North America, Australia, and Europe, the typical fractionation schedule for adults is 1.8 to 2 Gy per day, five days a week.
* In some cancer types, prolongation of the fraction schedule over too long can allow for the tumor to begin repopulating, and for these tumor types, including head-and-neck and cervical squamous cell cancers, radiation treatment is preferably completed within a certain amount of time.
* For children, a typical fraction size may be 1.5 to 1.8 Gy per day, as smaller fraction sizes are associated with reduced incidence and severity of late-onset side effects in normal tissues.
* In some cases, two fractions per day are used near the end of a course of treatment.

This schedule, known as a concomitant boost regimen or hyper fractionation, is used on tumors that regenerate more quickly when they are smaller.

**Q.NO.3: write the interaction of matter photoelectric effect and Compton effects?**

**Ans:**

**Photoelectric effect:**

In this process, an incoming photon undergoes a collision

with a tightly bound electron. The photon transfers practically all of its

energy to the electron and ceases to exist. The electron departs with most of

the energy from the photon and begins to ionize surrounding molecules. This

interaction depends on the energy of the incoming photon, as well as the atomic

number of the tissue; the lower the energy and the higher the atomic number,

the more likely that a photoelectric effect will take place.

An example of this interaction in practice can be seen on a diagnostic x-ray

film. Since the atomic number of bone is 60% higher than that of soft tissue,

bone is seen with much more contrast and detail than is soft tissue. The energy

range in which the photoelectric effect predominates in tissue is about 10-25 keV.

**Compton Effect**:

The Compton Effect is the most important photon-tissue interaction for the treatment of cancer. In this case, a photon collides with a “free electron,” i e, one that is not tightly bound to the atom. Unlike the photoelectric effect, in the Compton interaction both the photon and electron are

scattered. The photon can then continue to undergo additional interactions,

albeit with a lower energy. The electron begins to ionize with the

energy given to it by the photon.

The probability of a Compton interaction is inversely proportional to the energy

of the incoming photon and is independent of the atomic number of the

material. When one takes an image of tissue using photons in the energy range

in which the Compton effect dominates (~25 keV-25 MeV), bone and soft tissue

interfaces are barely distinguishable. This is a result of the atomic number

independence.

The Compton effect is the most common interaction occurring clinically, as

most radiation treatments are performed at energy levels of about 6-20 MeV.

Port films are films taken with such high-energy photons on the treatment

machine and are used to check the precision and accuracy of the beam; because

they do not distinguish tissue densities well, however, they are not equal

to diagnostic films in terms of resolution.

**Q.NO.4: Write a note on brachytherapy?**

**Ans:**

**Brachytherapy:**

* Brachytherapy (internal radiation therapy) is delivered by placing radiation source(s) inside or next to the area requiring treatment.
* Brachytherapy is commonly used as an effective treatment for cervical, prostate, breast, and skin cancer and can also be used to treat tumors in many other body sites.
* As with stereotactic radiation, Brachytherapy treatments are often known by their brand names.
* For example, brand names for breast cancer brachytherapy treatments include SAVI, MammoSite, and Contura.
* Brand names for prostate cancer include Proxcelan, TheraSeed, and I-Seed.
* In Brachytherapy, radiation sources are precisely placed directly at the site of the cancerous tumor.
* This means that the irradiation only affects a much localized area – exposure to radiation of healthy tissues further away from the sources is reduced.
* These characteristics of Brachytherapy provide advantages over external beam radiation therapy – the tumor can be treated with very high doses of localized radiation, whilst reducing the probability of unnecessary damage to surrounding healthy tissues.
* A course of Brachytherapy can often be completed in less time than other radiation therapy techniques. This can help reduce the chance of surviving cancer cells dividing and growing in the intervals between each radiation therapy dose.
* As one example of the localized nature of breast brachytherapy, the SAVI device delivers the radiation dose through multiple catheters, each of which can be individually controlled.
* This approach decreases the exposure of healthy tissue and resulting side effects, compared both to external beam radiation therapy and older methods of breast brachytherapy.
* Brachytherapy is the term used to describe radiation treatment in which the radiation source is in contact with the tumor. This therapy contrasts with external beam radiotherapy, in which the radiation source is 80-100 cm away from the patient.
* In brachytherapy, dose distribution is almost totally dependent on the inverse square law because the source is usually within the tumor volume. Because of this inverse square dependence, proper placement of radiation sources is crucial.

**Q.NO.5: Explain how volumetric modulated are therapy works for the cancer body?**

**Ans:**

 **Volumetric modulated arc therapy (VMAT):**

* Volumetric modulated arc therapy (VMAT) is a new radiation technique, which can achieve highly conformal dose distributions on target volume coverage and sparing of normal tissues.
* The specificity of this technique is to modify the three parameters during the treatment. VMAT delivers radiation by rotating gantry (usually 360° rotating fields with one or more arcs), changing speed and shape of the beam with a multileaf collimator (MLC) ("sliding window" system of moving) and fluence output rate (dose rate) of the medical linear accelerator.
* VMAT also has the potential to give additional advantages in patient treatment, such as reduced delivery time of radiation, compared with conventional static field intensity modulated radiotherapy (IMRT).

 **Particle therapy:**

* In particle therapy (proton therapy being one example), energetic ionizing particles (protons or carbon ions) are directed at the target tumor. The dose increases while the particle penetrates the tissue, up to a maximum (the Bragg peak) that occurs near the end of the particle's range, and it then drops to (almost) zero. The advantage of this energy deposition profile is that less energy is deposited into the healthy tissue surrounding the target tissue.

 **Auger therapy:**

* Auger therapy (AT) makes use of a very high dose of ionizing radiation in situ that provides molecular modifications at an atomic scale.
* AT differs from conventional radiation therapy in several aspects; it neither relies upon radioactive nuclei to cause cellular radiation damage at a cellular dimension, nor engages multiple external pencil-beams from different directions to zero-in to deliver a dose to the targeted area with reduced dose outside the targeted tissue/organ locations.
* Instead, the in situ delivery of a very high dose at the molecular level using AT aims for in situ molecular modifications involving molecular breakages and molecular re-arrangements such as a change of stacking structures as well as cellular metabolic functions related to the said molecule structures.

 **{“THE END”}**