Radiopharmaceuticals and Contrast Media

Lec: 7
Radiopharmaceuticals

• Radioisotopes

➢ every atom of an element is composed of a nucleus, containing protons and neutrons, surrounded by electrons.

➢ In the electrically neutral atom, the number of electrons is equal to the number of protons in the nucleus.

➢ Furthermore, the number of protons in the nucleus is equal to the atomic number of the atom.
Most elements contain a certain percentage of atoms which differ in atomic weight or mass from the majority of the atoms present.

These different forms of an element are known as isotopes, and they vary in the number of neutrons contained in the nuclei of their atoms.
Isotopes of a particular elements, then, have the same atomic number (same number of protons) but different mass numbers (differing numbers of neutrons).

The isotopes of a particular element have the same chemical and physical properties.
The only variation that is usually found is in the kinetics or rates of chemical reactions involving the isotopes, since the mass is a very important aspect of reaction rates.
Two major types of isotopes are found in nature:

- **Stable isotopes** maintain their elemental integrity, and do not decompose to other isotopic or elemental forms.

- **Unstable or radioactive isotopes**, however, decompose or decay, by emission of nuclear particles, into other isotopes of the same or different elements, the decay is a characteristic for a particular isotope, and continues until a stable isotopic level is achieved. Since the transition from one isotope to another, whether it is within the same element or not, involve a nuclear transformations.
Biological Effects of Radiation

• The effect of radioactive particles impinging upon biological tissue depends upon a number of factors:
  • 1. The ability of the radiation to penetrate tissue,
  • 2. The energy of the radiation
  • 3. The particular tissue and surface area exposed
  • 4. The dose rate of the radiation.
• The destructive aspect of radioactivity is directly related to its interaction with molecules present in the tissue to form abnormal amounts of ions and/or free radicals.

• These chemical species can alter the local pH or serve to initiate free radical chain reactions, resulting in the production of peroxides or other toxic compounds.
• These and other events can create a hostile environment for tissue cells, leading to necrosis and, ultimately, complete destruction of the tissue or organ.

• Water is the most abundant molecule in most tissues and is the most probable reactive species in the path of ionizing radiation, although other biochemicals may be involved.
• Before radiation can produce any damage, it must first gain entry into the tissue, various types of radiation differ significantly in their abilities to penetrate tissue or other media.
• Although alpha particles have a potential to produce a tremendous amount of ionization or free radicals, isotopes emitting alpha particles must be directly applied to the tissue, in most cases, in order to observe biological effects.

• The range and penetration of these particles are so slight that even if an individual were close enough for the radiation to reach the skin, the particles would not penetrate the surface.
• The opposite characteristic is found in gamma radiation.

• Although the ionizing power of gamma rays is relatively low, the range and penetrating ability of this type of radiation are high enough to produce significant damage at distances of several meters from the source.

• The damage is produced through collision reactions with atoms comprising the tissue.
Internal administration of radioisotopes.

- There are a number of preparations containing radioisotopes which are used internally for therapeutic and diagnostic purposes.
- These preparations are referred to collectively as radiopharmaceuticals.
• Isotopes important as radiopharmaceuticals are, **first** of all, those emitting beta or gamma radiation.

• **Secondly**, many of these isotopes are concentrated in a specific manner in certain organs or cells, e.g., I\(^{131}\) in thyroid tissue. Areas of heavy concentration are known as hot spots" while areas where concentration is light are known as "cold spots"."
• Sometimes the isotope must be incorporated into or "tagged" on to a molecule which aids in directing it into a particular tissue with some degree of specificity.

• Due to the potential hazard of radioisotopes, selective absorption and distribution are important factors to be considered in their use.

• Thirdly, the isotopes should be able to be eliminated from the body easily and, aside from the associated radioactivity, they and the decay products should be of low toxicity.
Radiopharmaceutical preparations

• **1. chromium-51** (sodium chromate Cr 51 injection):
  - It is used diagnostically to determine red blood cell mass, volume, and survival time, and for scanning the spleen.
  - Chromium in the +6 oxidation state [Cr(VI)] is readily taken up by erythrocytes and becomes fixed to the globin portion of haemoglobin as chromium(III).
2. Cobalt -57 and 60

• **Cyanocobalamin Co 60 Capsules and Solution:**

• They are used in diagnostic procedures for pernicious anaemia, the basis of the test suppose that if vitamin B12 is absorbed from the GIT, it will be excreted in the urine.

• Therefore, the radio activity from an oral dose of 60Co-labeled vitamin B12 should be detectable in the urine of the normal patient, and absent or at significantly lower levels in the urine of the patient with pernicious anaemia.
3. Iron-59(Ferrous Citrate Fe 69 )

• The isotope is employed in diagnostic procedures relating to various aspects of iron metabolism and red blood cell formation.

• The preparation can be administered orally to study the absorption of iron from the GIT, and injected intravenously for determinations of plasma iron clearance, turnover, and the incorporation of iron into erythrocytes.
4. **Gold-198** (Gold Au 198 Injection)

- Gold-198 solution is most frequently used therapeutically.
- The solution is administered by intracavitary injection into the pleural and peritoneal cavities as an aid in the management of pleural effusion and ascites, these fluid accumulations when secondary to neoplastic disease in the area.
5. Iodine-125 and -131
(Sodium Iodide I 125 Solution, Sodium Iodide I 131 Capsules and Solution)

- **Sodium iodide I\(^{131}\)** is the most common isotope and chemical form in use as a diagnostic aid in the study of the functioning of the thyroid gland and in scanning the thyroid to determine size, position, and possible tumour.

- **I\(^{131}\)** is also employed therapeutically to destroy thyroid tissue.
6. Mercury-197 and 203(mercuric Hg 197,203 injection)

- Chlormerodrin labelled with either 197Hg or 203Hg is a special radioactive tracer for making scintillation scans of the kidneys or the brain.
• This compound is in the chemical class of mercurial diuretics, which are generally taken up by the cells of the proximal kidney tubules in the renal cortex.

• The excretion from these cells is slow enough to allow scanning procedures of the kidneys to determine the presence and location of cysts, tumours, or other abnormalities.
7. Phosphorus-32 (Sodium Phosphate P 32 Solution)

- Solution is used for both diagnosis and treatment of various neoplastic diseases.
- Phosphate is utilized in cell metabolism. Those cells which are rapidly proliferating have the highest turnover of phosphate.
- Tumour cells are characterized as being rapidly proliferating, and will, therefore, accumulate phosphate labelled with 32P to a greater extent than non-cancerous cells.
Radiopaque Contrast Media

- Radiopaque media are chemical compounds containing elements of high atomic number which will stop the passage of x-rays.
- These types of compounds are used as diagnostic aids in radiology or roentgenology.
- Roentgenology involves the use of x-rays (roentgen-rays), which are short wavelength electromagnetic radiation, in the imaging or shadowing of various internal organ structures.
• X-rays are capable of passing through most soft tissue so that when special photographic film or a photosensitive plate is placed on the side of the patient opposite to the x-ray source, the film or plate will become darkened in an amount proportional to the number of x-rays that are able to pass
• Bone and teeth are the only types of tissue capable of significantly arresting the passage of x-rays.

• These structures will appear light on exposed x-ray film, allowing their visualization for the diagnosis of fractures, malformations, and the like.
• **Barium Sulfate:**

• Barium sulfate is the agent of choice in roentgenographic studies of the GIT.

• Its insolubility in acidic gastric juice is a major criterion for this use, since soluble salts would produce toxic barium ion.

• Other insoluble compounds, i.e., the oxide, carbonate, sulfide, and phosphate, will exhibit some solubility in the acidic medium of the stomach.
• **Barium sulfate** is employed in suspensions of various concentrations for use in the GIT.

• A paste of the compound will remain in the oesophagus long enough for roentgenographic or fluoroscopic study.

• The suspensions are administered orally or by enema after fasting.
Organoiodine Radiopaque Compounds

- There are a number of official iodine-containing organic compounds used in diagnosis by roentgenography.

1. Meglumine Diatriwate, and Sodium Diatriwate
   - These agents are used in cerebral angiography, urography, pyelography, and gastrointestinal studies.
2. Meglumine Iodipamide, and Sodium Iodipamide

- Both of these are used in cholangiography (roentgenography of the bile duct).

3. Iodized Oil:

- This is a preparation of iodized poppy seed oil used in hysterosalpingography (roentgenography of the uterus and oviduct).
4. Iopanoic Acid:
- This is a compound of low toxicity used in cholecystography (visualization of the gall bladder).

5. Iophendylate:
- This used in myelography (visualization of the spinal subarachnoid space).

6. Calcium Ipodate, and Sodium Ipodate:
- These are cholecystographic agents for oral use.