Radio-isotopes in Clinical Medicine

Radiactive isotopes, whether naturally occurring or artificially produced, have a number of different uses in clinical medicine.
These include:

(1) Diagnostic and research purposes in radiotracer scans (unsealed)
(2) As sources for teletherapy and brachytherapy (sealed)
(3) Internal therapeutic administration (unsealed)

Radioisotopes in Diagnosis:

Unsealed radioisotopes are normally conjugated with substances which enter into and participate in metabolic pathways-these labeled substances are called radiopharmaceuticals. These can then be followed or imaged by suitable radiation detectors (usually scintillation counter or gamma camera) which detect the gamma rays emitted by the substances inside the body.

Selection criteria:

(1) Tracer substance should be identical in chemical and biological properties to the corresponding stable substance.
(2) The labeling radioisotope should remain firmly attached with the tracer substance throughout the investigation.
(3) The radioisotope should have as short a half-life as feasible for the investigation, to reduced unnecessary radiation hazard to the patient.
(4) The radioisotope should ideally be a pure gamma-emitter as accompanying beta and alpha rays will only increase the radiation dose without contributing anything to the sensitivity of the scanning process. Thus the best isotopes are radio-isomers, ie excited atomic nuclei which retain their gamma energy for some time- a further advantage of these molecules are their relatively short half-lives. Technetium 99m is the best radio-isotope for diagnostic purpose, being a pure gamma emitter with a short half-life of only 6 hours.
(5) The energy of the isotope should be sufficiently high for it to easily penetrate the body tissues to reach the detector while at the same time being low enough not to create any significant problems with radiation protection.

Production of radio-isotopes:
In generators/cows. The parent isotopes are kept adsorbed onto Alumina in cylindrical columns inside glass funnels, protected by nylon meshes. The required radioisotopes are usually obtained by washing (or elution) with saline. The parent element for Tc99m is Mo99 and for I32 is Te132.

Type of Test	*Test*	*Radioisotope*
Metabolic & physiological	Thyroid function test	I-131, Tc-99m
	Renal function	I-132
	Vit B12 & pernicious anemia	Co-57
	RBC survival time	Cr-51
	Detection of melanoma	P-32
	Total blood volume	Cr-51
	Plasma volume	I-125
Organ visualisation	Thyroid	I-131, Tc-99m
	Brain	Tc-99m
	Liver	Tc-99m
	Bone	Tc-99m
	Spleen	Cr-51

Radioisotopes in Teletherapy: (All isotopes and/or their daughter products are gamma emitters)

Radioisotope	*Half-life*	*Energy*	*Exposure rate constant ($R\ cm^2h^{-1}Ci^{-1}$)*	*Production*	*Decay Product*
Radium	1622 years	0.04-2.45 MeV (avg= 0.83 MeV)	8.25	Naturally occurring (decay product of U-238)	Pb-206
Cesium	30 years	0.662 MeV	13.07	Nuclear reactor (fission product of U-235, produced by neutron bombardment)	Ba-137
Cobalt	5.26 years	1.17 MeV, 1.33 MeV (avg. 1.25 MeV)	3.26	Nuclear reactor (neutron bombardment of Co-59)	Ni-60

Additional Radioisotopes in Brachytherapy: (besides Radium-226, Cobalt-60 and Cesium-137)

Radioisotope	*Half-life*	*Energy*	*Exposure rate constant ($R\ cm^2h^{-1}Ci^{-1}$)*	*Production*	*Decay product*	*Applications*
Ir-192	73.8 days	0.38 MeV	4.69	In nuclear reactor (neutron bombardment of Ir-191)	Pt-192	LDR-ISRT, HDR-ICRT, ISRT, intravascular brachytherapy
Au-198	2.7 days	γ	_	_	_	Permanent interstitial
I-125	59.4 days	γ	_	_	_	Permanent interstitial
Pd-103	17 days	γ	_	_	_	Permanent interstitial
Sr-90-Y-90	28.9 years	β	_	_	_	Ocular plaque

Additional Isotopes in intravascular brachytherapy:

Y-90→ β
W-188-Re188→ β
P-32→ β
Re-188→ β
Ru-106-Rh-106→ β
V-48→ β

Developmental Radio-isotopes:

Am-241→ γ
Yb-169→ γ
Cf-252→ neutron
Cs-131→ γ
Sm-145→ γ

Radiopharmaceuticals in Internal Therapeutic Use:

Radiopharmaceutical	*Half-life*	*Emission*	*Applications*	*Administration*
I-131 Sodium iodide	8 days	β,γ	(1) Treatment of hyperthyroidism (2) Definitive treatment & palliation of Ca.thyroid	Oral(30 mCi) Oral(150-250 mCi)
P-32 Sodium phosphate	14.3 days	β	Treatment of myeloproliferative disorders (Primary Polycythemia Vera & Thrombocytosis)	IV (<5mCi)
P-32 Chromium phosphate	14.3 days	β	Intracavitary treatment of malignant effusions	Intra-pleural /intra-pertitoneal (10-20 mCi)
Sm-153-EDTMP	1.9 days	β,γ	Palliation of painful bone metatstasis	IV
Sr-89 Strontium chloride	50.5 days	β,γ	Palliation of painful bone metatstasis	IV
Re-186 Renium HDP	3.8 days	β,γ	Palliation of painful bone metatstasis	IV

Desirable characteristics of therapeutic nonsealed radioisotopes:

(1) High LET (best to use β or α-emitters or radionuclides that decay by electron capture and internal conversion to emit X-rays)
(2) Short effective half-life (in days)
(3) High target-nontarget ratio
(4) Deliver minimal radiation dose to medical personnel
(5) Readilty available at reasonable cost

Side effects:

(1) Sr-90 , Sm-153, Re-186, P-32 (IV)→Bone marrow depression (especially thrombocytopenia)
(2) P-32 (intra-peritoneal) N+V, diarrhea, pain abdomen, bowel obstruction
(3) I-131→ Thyroiditis, oesophagitis, gastritis, sialoadenitis, xerostomia.

Radioisotopes in Radioimmunotherapy:

In radioimmunotherapy. Radioisotopes (usually beta emitters) are conjugated with monoclonal antibodies. The MAbs home to cells expressing the relevant antigens while the bystander cells which do not express MAbs can also be killed by the beta-rays emitted by the radioisotopes (as cross-fire effect). Mainly used in relapsed and refractory

hematopoietic malignancies. May be used as pre-targetted radioimmunotherapy, where a radiopharmaceutical is first administered and allowed to concentrate in the diseased tissue and then an activating substance is administered to activate cell kill which is localized to the target organ/ tissue.

Radioimmunoglobulin	*Radioisotope*	*MAb*	*Applications*
Ibritumomab tiuxetan (Zevalin)	I-131	Anti-CD 20	Relapsed and refractory low-grade NHL
Tositumomab (Bexxar)	Y-90	Anti-CD 20	

Non-sealed radio-isotopes:

Precautions: It is mandatory to check that female patients are not pregnant.

If IV administration is to be done, it should be ensured that IV line is free-flowing

Proper guidelines should be followed in preparation, administration and documentation of the radio-isotopes.

Proper guidelines should be followed in case of leakage or spillage of unsealed radio-isotopes for evacuation, decontamination and notification.

Patients are not be discharged from care until the activity of the remaining radioisotope in their bodies has dropped to below 30 mCi and the total effective dose equivalent to any other individual is below 5 mSv.

While the patient is kept admitted , all body effluents should be properly flushed in the toilet while all trash and nondisposeable items must be stored until radiation levels are normalized.

Dosimtery of therapeutic radio-isotopes:

(1) Empiric method /fixed administered activity
(2) Delivered dose method.