

# M.Sc. Nuclear Medicine Technology and Hospital Radiopharmacy

*Programme Code:* HLTH20

*Programme Outcome:*

- To develop human resource, in the form of Radio pharmacist, for nuclear medicine departments of various hospitals in the country, possessing specialized knowledge in operation of Medical Cyclotron, formulation of various radiopharmaceuticals for diagnosis (PET & SPECT) and therapy
- To understand techniques in Scintigraphy and PET-CT for application of radioisotopes in diagnostic and therapeutic nuclear medicine.
- To acquire the knowledge about the use of radioisotopes in laboratory applications like radioimmunoassay (RIA), Immunoradiometric assay (IRMA) and other related methods.
- To develop theoretical and practical knowledge and the required competencies to function in a nuclear medicine setup and to setup new nuclear medicine facilities.
- **Hospital Radio pharmacy**  
To understand various radiopharmaceutical preparation techniques and their quality control, mechanism of action and clearance of from human body for the understanding of various patho-physiological conditions.  
To understand and adopt appropriate quality assurance practices in the delivery of nuclear medicine services. To learn and strengthen knowledge related to basic sciences applied in nuclear medicine.
- **Medical Cyclotron Operation**  
To understand and apply the knowledge of medical cyclotron, its radiation safety. To gain knowledge and training on Medical Cyclotron operation for regular PET isotope production.
- **Instrumentation & Imaging techniques**  
To understand and apply knowledge of radiation detectors and various imaging and non-imaging equipment like Uptake probe, Gamma Camera, SPECT, PET, Intraoperative Probes in a nuclear medicine laboratory. Role and application of complimentary imaging.
- **Basic radiochemistry and radiation biology**  
Understand and apply nuclear medicine related concepts of nuclear physics, detectors like gas filled, liquid scintillation, organic and inorganic scintillation detectors, & semiconductor detectors, counting statistics, gamma ray spectrometry, radiation biology, personnel monitoring devices, radiation protection & dosimetry, radioactive material transport & waste management, radiation emergencies & preparedness in nuclear medicine setup.
- **Regulatory aspect of MCF & RP Labs**  
To learn and apply principles of radiation protection in nuclear medicine laboratories. To be able to assume responsibility as Nuclear Medicine Physicist, Imaging Technologist, Radiopharmacist and give orientation to function as Radiation Safety Officer.

## DETAILED COURSE STRUCTURE

CORE COURSE				
Semester	Course Code	Subject Title	Lectures (Hours)	marks
Semester I	01-HLTH20-601-C	Basic science in Nuclear Medicine	49	100
	01-HLTH20-602-C	Basic Radiochemistry, Radiation detection and measurements	45	100
	01-HLTH20-603-C	Radiation Biology & Health Physics	40	100
Semester II	01-HLTH20-604-C	Production of Radioisotope for Nuclear Medicine	30	100
	01-HLTH20-605-C	Hospital Radiopharmacy	35	100
	01-HLTH20-606-C	Instrumentation & Imaging Technology	56	100
	PRACTICAL 1	Radiation Protection Instruments and Quality Control		50
	PRACTICAL 2	Radiopharmacy, In-vitro and Non-imaging Techniques		50
Semester III	01-HLTH20-607-C	Cyclotron Operation for Routine Isotope Production	42	100
	01-HLTH20-608-C	PET Radiochemistry & Radiopharmacy	30	100
	01-HLTH20-609-C	Application of RPhs in Clinical medicine	47	100
Semester VI	01-HLTH20-610-C	Recent advances in Radiopharmacy	30	100
	01-HLTH20-611-C	Layout planning and Regulatory Aspects of MCF and RP Labs	30	100
	PRACTICAL 1	Cyclotron Operation		50
	PRACTICAL 2	Radiopharmacy		50
	Grand Viva Voice			100
<b>Total</b>			<b>434</b>	<b>1400</b>

## SYLLABUS FOR CORE COURSES

### HLTH20-601: Basic science in Nuclear Medicine (49 Lecture)

**Coordinators: Dr Mukti Kanta Ray**  
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**Dr. Shrinibas Nayak,**  
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#### *Course Details:*

- **Atomic structure & Periodic table**

Atom and sub atomic particles, Rutherford's atomic structure and its limitations, Bohr's atomic structure. Quantum numbers, Isotope, Isobar and Isotone, Periodic properties like atomic radius, ionic radius, Electro negativity, Ionisation potential, Electron affinity.

- **Organic Chemistry**

Concept of Bohr model, Hybridization with example of Methane, Ethylene and acetylene etc, Solvent strength, acid base, pH, buffers, titrations, Basic Organic Chemistry, resonance effect, steric effect, dielectric constant, various type of organic solvents, mesomeric effect, determination of organic acid base strength and other organic phenomena utilizing the basic principle, various type of organic reactions, Nucleophilic Substitution reactions in details, Aromatic substitution reactions.

- **Mathematics**

Numbering system, Accuracy and Precision, Significant figures, Matrices, Mathematical Constants. Linear and Polynomial Equations, Linear and Quadratic Equations and Identities, Slope, Roots, Relation between Roots and Coefficients. Logarithms; Definition, Laws of Logarithms, Rule for Change of Base, Common and Natural Logarithms, Permutations and Combinations, Probability, Factorials. Calculus; Relations and functions, Limits, Definition of Derivative, Physical Significance, Differentiation of Simple Functions, Differential Equations, integration and Summation, Definition of Trigonometric Functions, Identities. Introduction to Mathematical Transformation: Fourier Transform, Laplace transforms.

- **Biostatistics**

Basic Concepts: Probability, a Priori and posteriori Probabilities. Statistical significance of probabilities Sample and Population, Variables, Classification of Variables, Nominal, Ordinal, interval and Ratio, Fixed and Random, Population Distributions: Binomial distributions and Poisson distributions – their properties, parameters and applications. Normal and 't' distributions – Population and Sample Parameters. Measures of central tendency, measures of dispersion, Variance, degrees of freedom, confidence limits and intervals. Probability of occurrence – use of Z and t tables. Sampling, Estimates and Hypothesis testing: Sampling methods, Random sampling and estimates of population parameters from samples. Sample statistics, Hypothesis testing. Drawing inferences and confidence limits. P values. Student's t test for comparing means.

General and paired t tests. Special cases where Variances are unequal. Central Limit Theorem. Analysis of Variance- F- Distribution, Test for Homogeneity of Variance One Way ANOVA, Comparison of Means of Multiple Groups By Partitioning of the total Sum of Squares as within and between Sum of Squares, Assumptions in ANOVA, Missing Values, Two Way ANOVA; Design of

Experiments. Correlation and Regression: Pearson's Product Moment Correlation Coefficient,

comparison of Correlation Coefficients, Partial and Multiple Correlation, Linear Regression Analysis Interpretation of Regression Coefficients. Application of Correlation and Regression in Method Comparison and Evaluation. Nonparametric Statistics: Spearman's Coefficient of Rank Correlation, Chi Square Test. Nonparametric Methods for Hypothesis Testing Based on Ranks. Mann Whitney U Test, Wilcoxon Signed Rank test, T Test. Clinical Statistics: Cohort Studies, Case Control Studies, Sample Size calculations, Clinical Trials, Meta analysis. Demonstration of application Software's in Statistics.

▪ **Electronics**

Fundamentals of electricity and electronics, Coulombs law, Ohms law, Ohmic & non Ohmic devices, Kirchhoff's law, regulated power supply, Semiconductor physics, PN junction diode, LED, rectifiers, transistors (PNP & NPN), feedbacks, operational amplifiers, Oscillators, binary, octal, hexadecimal number system, logic circuits, CRO, ADC and DAC. Defibrillator circuit and uses.

▪ **General Cell Biology & Cellular Physiology**

The basic structure of eukaryotic and prokaryotic cell and their internal environment. Cell wall, cell membranes. Functions of endoplasmic reticulum, mitochondria, Golgi complex, lysosomes. Transmembrane potential of mitochondria and its implications in transport and intramitochondrial localization of isonitrile compounds. Transport across cell membranes, Functional systems in the cells. Cell cycle and cell division, Cell reproduction; Concept of Cell doubling time and its implication in Oncology.

▪ **Introduction to Immunology**

Structure and function of immune system, cells of the Immune system, humoral and cell-mediated immune response— primary and secondary responses and their applications, polyclonal and monoclonal antibodies , basic characteristics of antigens/antibodies, structure and classification of antibodies, antigen-antibody interactions, methods of estimation of Ag, Ab and their relevance in disease detection, production and purification of polyclonal antibodies, primary & secondary immune response, disadvantages of using polyclonal antibodies, Hybridoma & other techniques for production of monoclonal antibodies and their fragments, in vitro applications in diagnostics, in vivo applications of monoclonal antibodies & fragments, conjugated antibodies, radiolabelled monoclonal antibodies, production, isotopes used, mechanism of localization, factors effecting localization, implications in imaging & therapy, new generation antibodies, Cells & important cytokines, host directed immune therapies, immunobiology of cancer.

▪ **Biochemistry and Molecular biology**

Introduction to Biochemistry includes carbohydrates, proteins, nucleic acids, enzymes, lipids. Protein structure and protein 3-dimensional shape, structure-function relationship, proteins purification, Importance of Amino acids in Nuclear Medicine, Nature of enzyme catalysed reactions, their regulation, inhibition and mechanisms. Structure and function of carbohydrates and their importance in central metabolism. Importance of Enzymes – Clinical Biochemistry, Structures and nature of fatty acids and lipids found in biological membranes. Introduction to Molecular Biology, Nucleic Acids and Biological Information Flow. PCR and Recombinant Technology for cloning of important Human proteins. Related Biochemical and molecular biology techniques. Aptamers with radiolabelled aptamers for nuclear imaging and therapy.

▪ **Basic Medical Terminology**

Descriptive – describing shape, colour, size, function, etc, and eponyms. Word root for e.g. Myocarditis (prefix)(root)(suffix). Prefix change, Suffix change. -itis, -osis, -ectomy, -otomy, -ostomy, a/an -, micro -, macro -, mega -/ -megaly, -scopy/ -scopic with examples. Pathological

Nomenclatures Specially for Tumours.

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- **Human Anatomy & Physiology**  
Introduction, definition of anatomy, definition of physiology- musculoskeletal system, cardiovascular system, lymphatic system, respiratory system, gastrointestinal system, hepatobiliary system, genitourinary system, nervous system, endocrine system, receptor system  
(introduction, physiology and pathological conditions)
- **Introduction to Biology of cancer**  
Neoplastic processes. Inflammatory & Degenerative processes. Classification and nomenclature of neoplasms. Concept of Cell doubling time and its implication in Oncology; Warburg effect and its implications in metabolic imaging, Apoptotic pathway and role of Annexin V.
- **Introduction to common hospital practices**  
Pathogens, Disinfection methods, Sterilisation, Communicable diseases, Nosocomial infections, Hepatitis, HIV, Biohazards, Principles of asepsis - handling of contaminated swabs, used syringes and needles, Bio-waste management. Policies for management of Needle stick injury/Exposure to blood or body fluids.
- **First aid and Cardio Pulmonary Resuscitation** (Theory and Practical)
- **Tutorials**

**Course Outcomes:**

- Understand and strengthen concepts of human anatomy and physiology, basics of -cell biology, -immunology, -molecular biology, -biochemistry, chemistry, electronics, mathematics and statistics related to nuclear medicine.
- Obtain concepts on medical terminology, common hospital practices and biomedical statistics.

## HLTH20-602: Basic Radiochemistry, Radiation detection and measurements (45 Lecture)

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**Dr. Shrinibas Nayak,**  
[nayaks@barc.gov.in](mailto:nayaks@barc.gov.in)

### Course Details:

- **Radioactivity, Radioelements, Isotopes and Radionuclides**  
Discovery of Radioactivity, Radioactive Substances in Nature, Units(Becquerel & Curie) and definition of Radioactivity. Laws of radioactivity.Periodic Table of the Elements, Isotopes and the Chart of the Nuclides, basis of radioactivity (N/Z ratio). Stability and Transmutation of Nuclides, Mass defect and Binding Energies of Nuclei, Nuclide Masses.
- **Physical Properties of Atomic Nuclei and Elementary Particles**  
Properties of Nuclei, Elementary Particles and Quarks
- **Decay Modes**  
Radioactive decay, Physical Half-Life, Activity, Decay Constant, Mode of radioactive decay, Types of radioactivity depending on N/Z ratio. Alpha particle decay, Beta particle decay, Gamma ray, Proton-Decay and Other Rare Decay Modes, Spontaneous Fission. X-ray emission, Theories of alpha, beta and positron emission; beta particle spectrum; K shell electron capture; Cerenkov radiation, characteristic radiation, Auger effect, Bremsstrahlung radiations, Metastable state and isomeric transition, internal conversion. Nuclear reactions, Nuclear reaction cross section, neutron activation with thermal neutrons, Nuclear isomerism, nuclear fission, fission products, nuclear reactors.
- **Radioactive Decay**  
Decay Series, Law and Energy of Radioactive Decay, Radioactive Equilibria, Secular Radioactive Equilibrium, Transient Radioactive Equilibrium, Half-life of Mother Nuclide Shorter than Half-life of Daughter Nuclide, Similar Half-lives, Branching Decay, Successive Transformations.
- **Interaction of Radiation with matter**  
Gamma ray interactions - Excitation, ionization, photoelectric effect, Compton effect, pair production, annihilation radiations, specific ionization and linear energy transfer; Charged Particle interactions: range of charged particles, Interaction of neutrons with matter, Elastic scattering. Importance of these interactions in radiology and nuclear medicine. Absorption, Scattering and Attenuation of Photons
- **Statistics of counting**  
Poisson distribution, Poisson approximation to radioactive decay, measures of counting error. Accuracy and precision, standard error, counting in low background and high background scenarios, net count rates and standard deviation of count rates. Gaussian distribution and propagation of errors. Distribution of counting times to minimize errors.

▪ **Radiation detection and measurement**

Simplified detector model. Modes of detector operation. Pulse height spectra. Counting curves and plateaus. Energy resolution. Detection efficiency. Dead time. Activity and Counting Rate, Choice of Detectors, Spectrometry, Determination of Absolute Disintegration Rates, Use of Coincidence and Anticoincidence Circuits, Low-level Counting, Neutron Detection and Measurement, Statistics and Errors of Counting, Track Detectors, Detectors Used in Health Physics.

▪ **Gas filled detector**

Theory of ionization chamber, design consideration in an ionization chamber, operating voltage, theory and construction of condenser type of chambers and thimble chambers; gas multiplication, pulse mode detector for single ionizing events, Proportional Counters - design and characteristics, Geiger-Mueller Counters - design consideration, dead time and recovery time, characteristics of organic and inorganic quenchers, pocket dosimeter, Dose calibrator, Zone monitors

▪ **Scintillation detectors - (Organic & Inorganic)**

Atomic basis of scintillation. Scintillation process. Dopants. Inorganic and Organic Scintillators, Comparison of properties by comparison of characteristics like stability, light output, decay time, intrinsic efficiency, dead time, considerations on fabrication and cost.

▪ **Gamma Ray Spectrometry**

Construction of a Gamma Ray Spectrometer. Components of GRS. Detection principle – light collection, light guide, and Photomultiplier tubes. Coincidence & anti coincidence circuits. Single channel analyzer, multi channel analyzer. Study of gamma ray spectrum: photopeak, Compton valley, edge and plateau, characteristic X-ray peak, backscatter peak, Iodine escape peak, annihilation peak, coincidence peak. Gamma ray spectrometer: calibration, energy resolution, integral & differential counting, linearity, counting efficiency.

▪ **Semiconductor detectors**

Semiconductors junction and surface barrier detectors, Diode detectors, Ge (Li) detectors, High Purity Germanium detectors, their response and characteristics, energy calibration and detector efficiencies, Cadmium-zinc-telluride detector. Room temperature semiconductor diodes. Advantages and disadvantages of semiconductor detectors.

▪ **Liquid Scintillation Counters**

Composition of liquid scintillator, scintillation cocktail: primary solute, secondary solute and organic solvent (toluene, 1, 4 dioxane, anthracene) and solubilizing agents for tissues, PM tubes, Coincidence circuits and count display systems. Quenching, Quench corrections methods: Internal standard method, external standard method and channel ratio. Discrimination of alpha, beta by liquid scintillations.

▪ **Radiation monitoring instruments**

Survey meters, area monitoring instruments, personal monitoring, Thermoluminescent Dosimeter (TLD) environmental monitoring, direct reading devices, calibration and response of radiation monitoring instruments.

**Course Outcomes:**

- Understand and apply the concepts of radioactivity, different types of radioisotopes, interaction of nuclear radiation with matter, different detectors viz. gas filled, liquid scintillation, organic and inorganic scintillation, & semiconductor, counting statistics, gamma ray spectrometry.

## HLTH20-603: Radiation Biology & Health Physics (40 Lecture)

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### Course Details:

#### ▪ **Radiation Biology**

Interaction of Radiation with cell: Radiolysis of water, interactions of free radicals, Direct versus indirect effects. Mechanism of radiation damage in living cells: Influence of LET, oxygen and various compounds on free radical forming reactions Target Theory, Multitarget theory, Target size, Multi hit theory, Multitarget multi hit theory.

Radiation effects on macromolecules, cell membrane, chromosomes. Chromosomal type aberrations. Radiation effects on cell division. Radiation effects on microorganisms and independent cell systems. Differential cell sensitivity. Criteria of sensitivity, Factors affecting sensitivity. Anti-oxidative enzymes: Super Oxide dismutase, Catalase, Glutathione reductase, Glutathione -S- transferase, Monoamine oxygenase, Glutathione peroxidase.

Radiation effects on major organ systems: hematopoietic system, digestive system, reproductive system, nervous system. Effects of Ionizing Radiation on the Embryo and Foetus. Teratogenic and delayed effects.

Linear Energy Transfer, Relative biological effectiveness, Dose rate effect, chronic irradiation, factors influencing radiation response - oxygen concentration, Temperature etc. Partial body and Whole Body Exposure

Acute radiation effects: Lethality, Stochastic and Non-stochastic effects of radiation: Late effects in normal tissue systems and organs, Radiation carcinogenesis, somatic & genetic effect of radiation, radiation induced mutations & Chromosomal aberration, dose effect relationship, pre-natal effects of radiation, types of genetic disorders, risk estimation, direct method, doubling dose method, uncertainties. Basis for ICRP dose limits for occupational exposure, embryo / fetus, members of the public, risks associated with recommended limits, Bio dosimetry, Bioassays, Extremity dosimetry. Low Dose Exposure to Ionizing Radiation: Medical, Natural background, Radon. Radiation Hormesis; BERT.

#### ▪ **Radiation Quantities and units**

Exposure (C/Kg & Roentgen), absorbed dose (Gray & Rad), LET Charged Particle Equilibrium (CPE), linear and mass attenuation coefficients, mass stopping power, air kerma, Radiation weighting factor (WR), Concept of radiation weighting factor WR, Sievert, Equivalent dose (Sievert & rem), Concept of tissue weighting factor WT, Effective dose (Sievert & rem), committed equivalent dose Committed effective dose, Collective Effective dose (Person Sv) ICRP and AERB dose limits. Use of dose constraints for staff and comforter. Annual Limit of Intake and derived air concentration. Reference levels: Recording levels, Investigation levels and Action levels.

#### ▪ **Personnel monitoring devices**

Film badges, Ring badges, Thermoluminescent dosimeters (TLD's), Pocket dosimeters. Characteristics of TLD phosphors, Glow curves, dose and energy response, sensitivity and application in dosimetry and personnel monitoring devices. Other types of dosimeters - radiation

calorimetry, photographic dosimetry, chemical dosimetry.

▪ **Radiation Protection**

Natural Background Radiation, concept of occupational risk, Types of exposure: internal and external exposure, Routes of internal exposure Principles of radiation protection, time, distance, shielding. Exposure rate & shielding calculations by defining types of materials, and thickness needed using attenuation coefficients. Concept of Half value layer and tenth value layer. Work place monitoring: Radiation field, contamination and airborne radioactivity monitoring, system of dose limitation, ALARA, dose limits to radiation workers and general public. AERB directive for derived working levels for radioactive contamination, airborne radioactivity and Radiation field. Radiation protection in diagnostic nuclear medicine, therapeutic nuclear medicine (with AERB directives for discharge of patients) and Medical cyclotron. AERB/ICRP recommendations, dose constraints for comforters of patients.

▪ **Radiation dosimetry**

Compartmental Model- Single compartmental model, two compartment model with and without back transference; in-vivo dosimetry using classical dosimetry mechanism; Metabolic pathways of radioisotope deposition, beta particle dosimetry; Equilibrium Dose rate equation. Gamma dosimetry and dose calculation, Specific gamma ray constant ( $\Gamma$ ) and average geometrical factor; dosimetry of low energy electromagnetic radiation; MIRD method of internal dose calculation, Absorbed Fraction and calculation of absorbed dose. Limitation of MIRD Method; extremity dosimetry.

▪ **Transport of radioactive material**

Classification of radioactive materials, general packing requirements, transport documents, Introduction of terms used (eg Competent Authority, A1 & A2 values, transport index (TI) etc) Type of package (Variety of packages covered under the transport regulations, general requirements of all packaging, requirements for transport of radioactive material in liquid form, preparation marking, labeling of packages), Transport Index, Category of package, approval requirements, Preparation of transport documents (Consignors Declaration TREMCARD instruction to the Carrier & Emergency in Writing). Off-normal situation during transport of radioactive materials, surface contaminated objects, handling of off-normal situations, emergency planning, responsibilities of consigner and consignee. Transport scenarios (routine normal & accident)

\*More detail on the Regulatory aspect of transport of Radioactive material and emergency preparedness related to transport of radioactive material will be covered in Semester IV Paper II.

▪ **Radiological emergency and preparedness**

Major spillage, loss of radioactive source, Misadministration, Medical emergencies involving radioactive patients and Death of therapy in-patient. AERB directives to handle the cadaver. Radioactive decontamination.

▪ **Radioactive waste management**

Philosophy of radioactive waste management, Classification of wastes and method of disposal, Management of solid waste, liquid waste and gaseous waste, Segregation, Collection and Safe disposal, Delay tank facility. Radioactive & Biohazardous Waste Disposal Methods - Decay in Storage, Separation by Half Life, Incineration, Sewer or Atmosphere. Airborne Radiation Exposure Measurements, Effluent Concentration (131-Iodine, 177-Lutetium, etc.). AERB directives for safe disposal of radioactive waste. Concept of Exclusion, exemption and clearance of radionuclide in solid materials. Disposal of animal carcasses and radioactive foliage, disposal limits for ground burial and sanitary sewage system, incineration, disposal of long-lived and in dispersible radioactive wastes.

▪ **Radiation Hazard evaluation and control**

Internal and external radiation hazards and their perspective evaluation and control of hazard due to external radiation, individual and workplace monitoring, application of time distance and shielding; specific gamma ray constant, external radiation monitoring, survey meters, internal hazard evaluation and control, protective measures for handling of unsealed sources ( e.g fumehood, glove box), environmental control, protective clothing, contamination monitoring and decontamination procedures, surface decontamination procedures.

This part of the syllabus will be covered in apprentice program at RHC unit RMC.

**Course Outcomes:**

- Understand and apply knowledge of effect of nuclear radiation on biological systems, quantification of effect of radiation on human body. Personnel monitoring devices, radiation protection & dosimetry, radioactive material transport & waste management, radiation emergencies & preparedness in nuclear medicine setup.

**HLTH20-604: Production of Radioisotope for Nuclear Medicine (30 Lecture)**

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**Course Details:**

- **Production of Radio-isotopes**

General consideration, Requirements of radiotracers, Different types of isotopes used in nuclear medicine, Radionuclide Considerations, Type and Energy of Emissions, Specific Activity, Radionuclidic Purity, Chemical Properties, Economy, Production of radionuclides. Equation for radionuclide production in Reactors and charged particle accelerators, irradiation yields, Target consideration, Second order reactions, Specific activity, NCA.

- **Nuclear Reactor produced radioisotopes**

Principle of production, Research reactors for isotope production, Nuclear reactions, Neutron energy and neutron flux, Cross-section, Types of nuclear reactions, Radiative neutron capture or (n,  $\gamma$ ) reaction, Neutron capture (n,  $\gamma$ ) followed by decay  $\beta$  decay, Neutron capture with particle emission: (n, p) and (n,  $\alpha$ ) reactions, Neutron capture with fission or (n, f) reaction, Calculation of radioisotope yield, Corrections to the activation equation, Self-shielding effect, Power variation in the reactors, Corrections for burn-up of the target and destruction of target atoms, Irradiation efficiency, Irradiation techniques, Choice of target material, Target encapsulation, Safety evaluation of in-pile irradiation and experimental assemblies.

- **Separation Techniques**

Chemical processing of reactor and accelerator targets; Separation techniques using precipitation, solvent extraction, distillation, gas evolution, ion exchangers; Structure of cation and anion exchangers; relative affinity of ions in exchangers; Use of exchangers in ion exchange columns; other column separation techniques.

- **Production and processing methods for individual radioisotopes**

$^{14}\text{C}$ ,  $^{51}\text{Cr}$ ,  $^{60}\text{Co}$ ,  $^{64}\text{Cu}$ ,  $^{131}\text{I}$ ,  $^{125}\text{I}$ ,  $^{192}\text{Ir}$ ,  $^{177}\text{Lu}$ ,  $^{99}\text{Mo}$ ,  $^{32}\text{P}$ ,  $^{103}\text{Pd}$ ,  $^{188}\text{Re}$ ,  $^{35}\text{S}$ ,  $^{153}\text{Sm}$ ,  $^{90}\text{Y}$ ,  $^{133}\text{Xe}$

- **Radionuclide Generators**

Need for Generator, Advantages of generator system, Definition, Properties of Ideal Generator, Basic Principle, Parent Daughter Growth –Decay Relationship, Parent Daughter Equilibrium, Transient Equilibrium, Secular equilibrium.

Types of radionuclide generator, column generator, solvent extraction generator, gel generator, sublimation generator, various generator systems, elution efficiency, Generator produced photon emitters, Generator produced positron emitters, Generator produced particle emitters for therapy

- Gamma emitting radionuclidic generators:  $^{99}\text{Mo}$  -  $^{99\text{m}}\text{Tc}$ ,  $^{113}\text{Sn}$  –  $^{113\text{m}}\text{In}$ , Special emphasis on  $^{99}\text{Mo}$  -  $^{99\text{m}}\text{Tc}$  generator: Production of parent, Decay Scheme, Characteristics of Daughter Radionuclide, Types of generators – column generator, solvent extraction generator, gel generator, sublimation generator, various generator suppliers, Applications of Daughter Radionuclide
- Beta emitting radionuclide generators:  $^{188}\text{W}$  /  $^{188}\text{Re}$ ,  $^{90}\text{Sr}$  /  $^{90}\text{Y}$ ,  $^{194}\text{Os}$  /  $^{194}\text{Ir}$ ,  $^{132}\text{Te}$  /  $^{132}\text{I}$ . Production of parent, decay Scheme, characteristics of daughter radionuclides, generator suppliers, applications of daughter radionuclide.
- Positron emitting radionuclide generators:  $^{68}\text{Ge}$  /  $^{68}\text{Ga}$ ,  $^{82}\text{Sr}$  /  $^{82}\text{Rb}$ : Production of parent,

Decay Scheme, Characteristics of Daughter Radionuclide, Various generator suppliers, Applications of Daughter Radionuclide.

- Alpha emitting radionuclide generators and Complex Systems:  $^{225}\text{Ac} / ^{213}\text{Bi}$ ,  $^{212}\text{Pb}/^{212}\text{Bi}$ .

- **First aid and Cardio Pulmonary Resuscitation** (Theory and Practical)
- **Tutorials**

**Course Outcomes:**

- Understand fundamental concepts of radioisotope production. Different types of radioisotopes used in nuclear medicine.
- Different ways for isotope production.
- Separation techniques.
- Nuclear Reactor produced radioisotopes.
- Nuclear generators

## HLTH20-605: Hospital Radio pharmacy (35 Lecture)

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### Course Details:

#### ▪ **Development of radiopharmaceuticals**

Definition of a Radiopharmaceutical, ideal Radiopharmaceutical, Important characteristics of a radionuclide to be used in imaging and therapy, with example of  $^{68}\text{Ga}$ ,  $^{177}\text{Lu}$ ,  $^{90}\text{Y}$ ,  $^{18}\text{F}$ ,  $^{99\text{m}}\text{Tc}$ ,  $^{131}\text{I}$ ,  $^{125}\text{I}$  etc., availability, short effective half- Life, particle emission, decay by electron capture or isomeric transition. High target to non-target activity ratio.

Design of new Radiopharmaceuticals. General considerations. Factors influencing the design of new radiopharmaceuticals. Empirical and Rational approaches to design, charge and size of the molecule, protein binding solubility, stability and bio-distribution. Structure- activity relationship. Biological properties of radiopharmaceuticals, pharmacokinetics, distribution, metabolism, excretion.

#### ▪ **Radiopharmaceutical Chemistry**

General physicochemical properties of radioactive compounds: distinction between radionuclide, radiochemical and radiopharmaceuticals, carrier concept (carrier-free, carrier added, no carrier added). Chemistry of tracer radionuclide metals: hydrolysis, reduction-oxidation, concentration methods, radiolytic decomposition.

$^{99\text{m}}\text{Tc}$ -chemistry, Core structures of various common  $^{99\text{m}}\text{Tc}$ - radiopharmaceuticals, labelling techniques, importance of  $^{99\text{m}}\text{Tc}$ -kit components, peptide chemistry with respect to  $^{68}\text{Ga}/^{177}\text{Lu}$ -DOTATOC, DOTA-TATE etc.

Study of Phosphorous (P), Chromium (Cr), Cobalt (Co), Iron (Fe), Indium (In), Thallium (Tl), Technetium- $^{99\text{m}}$ - Technitium (Tc), Iodine (I), Yttrium (Y), Strontium (Sr), Rhenium (Re), Samarium (Sm), Lutetium-177 (Lu), radioactive gases (i.e. Xenon  $^{133}\text{Xe}$ ,  $^{127}\text{Xe}$ ,  $^{81\text{m}}\text{Kr}$ ) & positron emitting nuclides like Fluorine ( $^{18}\text{F}$ ), Oxygen ( $^{15}\text{O}$ ), Carbon ( $^{11}\text{C}$ ), Nitrogen ( $^{13}\text{N}$ ), Copper ( $^{64}\text{Cu}$ ), Rubidium ( $^{82}\text{Rb}$ ), Gallium ( $^{68}\text{Ga}$ ).

#### ▪ **Modes of localization**

Localisation of radiopharmaceuticals in organ of interest for diagnostic and therapeutic purposes. Various Mechanism of localisation with respect to each radiopharmaceutical. Ideal characteristic of RP for modes of localisation: Active and passive modes of localisation. Substrate specific radiopharmaceutical localization, Receptor mediated biochemical, metabolic trapping, enzyme substrate, antibodies to tumor associated antigens. Filtration, Phagocytosis, Cell Sequestration, Capillary blockade, ion Exchange, Chemisorption, Cellular migration.

#### ▪ **Compartmental Analysis**

Compartmental analysis and its applications in Nuclear Medicine, Assumptions in Compartmental model, Single compartment model, The Continuously stirred tank reactor (CSTR); Single Compartment model: The Charged Capacitor; Single Compartment model: Discrete time analogues for two compartment systems; Occupancy theorem. Application of Differential equations, Open and closed models, Single compartment, two compartment and multicompartment models, reversible and

irreversible exchanges, Mammary and Catenary models, Problems on radioactive generators, biological elimination processes of radiopharmaceuticals. Distributed Models.

▪ **Methods of radiolabeling**

Methods of radiolabeling. Isotope exchange reactions. Introduction of a foreign label. Labeling with bifunctional chelating agents. Biosynthesis/Bio conjugation, Metal complexes. Important factors in labelling. Efficiency of the labeling process. Chemical stability of the product. Denaturation or alteration. Isotope Effect. Carrier-free or No- carrier-added state. Storage conditions. Purification analysis, shelf life.

▪ **Specific methods of labelling**

Chemistry of Technetium with respect to oxidation states, reduction methods, technetium tin-ligand reactions in aqueous solution, hydrolysis, re-oxidation, complexation, carrier effects, radiolytic decomposition.

Labelling with  $^{99m}\text{Tc}$ : formation of  $^{99m}\text{Tc}$ - complexes by ligand exchange, structure of  $^{99m}\text{Tc}$ -complexes, oxidation states of  $^{99m}\text{Tc}$  in radiopharmaceuticals and kits for  $^{99m}\text{Tc}$ -labeling-: DTPA, GHA, DMSA, MIBI, MAG3, MDP, phytates, ECD, EC, IDA compounds and Sulfur Colloid. Dextran colloid and labeled particles. Metal chelate and conjugates,  $^{99m}\text{Tc}$ -tricarbonyl core,  $^{99m}\text{Tc}$ -nitrido compounds,  $^{99m}\text{Tc}$ -Hynic, PNP

Kit formulation of radiopharmaceuticals and their classification. Additives, stabilisers and preservatives.

▪ **Radiolabeling of Cells**

Methods of labelling for blood pool studies and detection of gastrointestinal bleeding

$^{99m}\text{Tc}$ - RBC (i.e. In-vitro, In-vivo and modified In-vivo),  $^{99m}\text{Tc}$ - RBC's (denatured) for splenic imaging,  $^{99m}\text{Tc}$ - /  $^{111}\text{In}$ - Leucocytes (i.e. Methods of radiolabeling for inflammation / abscess localization),  $^{51}\text{Cr}$ - red blood cells (i.e. Methods of radiolabeling for blood volume measurement & Splenic Sequestration studies),  $^{111}\text{In}$ -platelets (i.e. Methods for radiolabeling).

▪ **Altered biodistribution related to improper preparation of Radiopharmaceuticals**

Radiopharmaceutical formulation problems, problems caused by radiopharmaceutical administration technique and procedure, changes in biochemical and pathophysiology, previous medical procedure such as surgery, radiation therapy and dialysis, drug interactions.

▪ **Quality control of Radiopharmaceuticals**

General Schemes, Physicochemical tests: physical characteristics, pH and ionic strength, radionuclide purity, radiochemical purity, chemical purity, radio assay.

QC of kits – radiochemical purity, sterility check, membrane filtration, chromatography, pyrogen test, bio- distribution studies, Molybdenum break through test. Breakthrough of methyl ethyl ketone, alumina. QC in hospital radiopharmacy practices - includes aseptic practices & pharmaceutical safety

aspects. Good manufacturing practice (GMP), ISO and ISI standards in radiopharmaceuticals. Adverse reactions to and altered biodistribution of radiopharmaceuticals, iatrogenic alterations in the biodistribution of radiopharmaceuticals Regulations, ethics and registration of radiopharmaceuticals.

▪ **Therapeutic applications of radionuclides**

Radionuclide therapy (RNT), definition, Problems for development of therapeutic RP, Uptake mechanisms of therapeutic radiopharmaceuticals, types of preparation, Properties of ideal therapeutic radiopharmaceuticals, selection of appropriate radionuclides includes particle emission, half-life,

Specific Activity, decay characteristics, characteristics of the ideal therapeutic radiopharmaceutical. Ranges of emitted particle radiation in the tissue: Beta particle emitting radionuclides: Response of beta particle radiation on tumor, classification of b- particles, Alpha particle emitting Radionuclides, Auger-electrons emitting radionuclides, properties of Auger-electron-emitting radionuclides. Dosimetry in therapy by Radiopharmaceuticals: Absorbed radiation dose, Patient Specific Dosimetry.

▪ **Radioisotopes: Beta particle emitting radioisotopes**

Phosphorus-32, Samarium-153, Holmium-166, Thallium-170, Rhenium-186, 188. Rhenium Chemistry, Rhenium-188, Production and Physical Characteristics, Issues with Column Generator Production, Uptake and Biokinetic Properties, Rhenium RPs. Role of radioiodine in therapy

Lutetium-177: Production and physical characteristics influence of production mode for  $^{177}\text{Lu}$ ,  $^{176}\text{Lu}$ -route versus  $^{176}\text{Yb}$ -route, Uptake and biokinetic properties, Peptide receptor radionuclide therapy, Dosimetry.

Yttrium-90: Production and physical characteristics,  $^{90}\text{Sr}/^{90}\text{Y}$  generators, uptake and biokinetic properties, uses of  $^{90}\text{Y}$  Radiopharmaceuticals: microspheres, MAA, antibodies, dosimetry.

Auger-electrons emitting Radioisotopes:  $^{111}\text{In}$  ( $^{111}\text{In}$ ): Production and physical characteristics, uptake and biokinetic properties, dosimetry. Application of therapeutic radiopharmaceuticals: Bone pain palliation, Radio synovectomy, Radio immunotherapy

▪ **Alpha emitting Radioisotopes for therapy**

$^{223}\text{Ra}$ -Radium-: Alpharadin, (Generator prod. RP  $^{227}\text{Ac} - ^{223}\text{Ra}$ ),  $^{212}\text{Bi}$  Bismuth, ( $^{212}\text{Bi}$  is produced by chemistry generator from  $^{224}\text{Ra}$ ),  $^{213}\text{Bi}$  Bismuth ( $^{213}\text{Bi}$  is produced by chemistry generator from  $^{225}\text{Ac}$ ),  $^{211}\text{At}$ -Astatium: (cyclotron produced RP.  $^{209}\text{Bi} (\alpha, 2n) ^{211}\text{At}$ ),  $^{225}\text{Ac}$ -Actinium: Cyclotron produced RP.  $^{226}\text{Ra} (p, 2n) ^{225}\text{Ac}$ . Production and physical characteristics, uptake and biokinetic properties.

**Course Outcomes:**

- Understand and apply knowledge of various radionuclides and radiopharmaceuticals used in clinical NM.
- Development of radiopharmaceuticals.
- Radiopharmaceutical chemistry of different isotopes. Modes of localization. Different methods of radiolabeling, quality control of different radiopharmaceuticals, bio distribution and clinical translation.
- Understand fundamental concepts of compartmental analysis.
- Learn and understand techniques applied in therapeutic nuclear medicine for choice of radionuclide and radiopharmaceuticals for therapy.

## HLTH20-606: Instrumentation & Imaging Technology (56 Lecture)

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**Dr. Shrinibas Nayak,**  
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### Course Details:

- **Isotope Calibrators & Probe systems**

Working principle of Isotope Calibrators and its QC; Thyroid uptake probe, basic components, system set-up and calibration, flat field collimator, iso-response curve and working distance. All quality control parameter including iso- response curve, and working distance. Its significance or application in non imaging procedures.

- **Overview of Whole-body counting system**

Whole body counting: principles of whole-body counting, design of whole-body counting system, stationary systems, single and multiple crystal systems, shadow shield geometry, moving systems, calibration of whole-body system, clinical and other applications of whole-body counters.

- **Collimator Systems**

Counting Geometry & Need for Collimator, Types of Collimator- Parallel Hole, Slant Hole, Rotating Hole, Focusing, Converging Hole and Diverging Hole Collimators, Material design with regards to Cost, Geometric Efficiency and Resolution. Pinhole Collimator and its Adaptation in Gamma Camera. Fan beam collimator, slit collimator, Slit slat collimator, Collimator in 2D PET.

- **Rectilinear scanner**

Block diagram, principle of working, effect of scanning speed, dot factor, time constant, line spacing, film density, information density, photo recording display, contrast enhancement and clinical applications. Focal plane and depth of focus.

- **Gamma Camera and quality control**

Scintillation camera, Basic principles of gamma camera, collimators, NaI (T) detector, position determining circuits, Display. Gamma camera-computer interface- ADC/DAC. Correction Circuits. Criteria of Selection & installation of Gamma camera, Frontiers of Gamma Camera Technology, LSF, MTF, Avalanche photodiodes, CZT detectors.

- **Single Photon Emission Computed Tomography & QC**

Principles of Tomography, longitudinal and transverse or axial tomography, Theoretical aspects of image acquisition & reconstruction techniques, filters, artifacts in SPECT, effect of scatter & scatter correction, noise, role of collimators, rotating gamma camera, single or multiple detector devices, data collection, SPECT acquisition – step & shoot/continuous. Whole body SPECT. SPECT v/s planar camera, SPECT v/s other modalities (CT, MRI, Ultrasonography)

- **Positron Emission Tomography Equipment & QC**

Gamma camera for PET imaging. Dedicated and hybrid PET systems. Principles of PET imaging, detectors assembly, various corrections in PET, 2-D and 3-D acquisitions, performance of PET imagers, sensitivity, spatial resolution. PET Detectors, Attenuation correction, TOF concept, instrumentation, data collection, data correction, data storage, reconstruction, quality control,

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Performance characteristics, NECR, NEMA specifications, PET v/s SPECT, PET Protocols.

- **Multicrystal Gamma Camera**  
Emerging designs and considerations of Multicrystal Gamma Camera. Small animal imaging systems.
- **Application of Computers in Nuclear Medicine**  
Image Acquisition Matrix, Byte Mode and Word Mode, Frame Mode Acquisition, List mode, Static, Dynamic and Gated Acquisition, Image Display methods, Image Perception and Analysis, Image Manipulations and Presentations, Background Correction Methods, Image Interpolation, Region of Interest Analysis, Time Activity Curves and General Filters and Normalization methods, Automated ROI's and Computational methods.
- **Medical Informatics**  
Image Formats, Concept of DICOM (Digital image communication in medicine) and DICOM-RT and etc, DICOM and interfile conversion software, Interfacing; TCP/IP protocols, PACS (Picture Archiving and Communication System); Telemedicine.
- **Non-imaging applications of radionuclides**  
51Cr labeled RBC's for blood volume, red cell volume measurement, spleen uptake, red cell survival studies. Schilling's test using 58Co/57Co for vitamin B12 absorption, applications of 14C radio respirometry for H.Pylori ulcers, Ferrokinetic studies using radioisotopes of Iron.
- **Diagnostic In-vitro Techniques:**  
Principle of RIA, Immunoradiometric assay (IRMA), Enzyme linked immunosorbent assay (ELISA), Fluorescent immunoassay (FIA), Chemiluminescent Immunoassay (CLIA), Methods of receptor assays. In-vitro Uptake studies, In- vitro radiorespirometry, Quality Control Parameters and methods and Applications for hormones & drugs, example of assays for T3, T4, TSH, free hormones, thyroid antibodies and thyroglobulin, other hormones and drugs.
- **Biomedical Ultrasound**  
Ultrasound generators, properties of ultrasound waves and its propagation in biological tissues, Pulse echo techniques, Scan types. Doppler principle.
- **Magnetic Resonance Imaging (MRI)**  
Basic Magnetism, Physics of magnetic resonance, MRI equipment its advantage over CT / Ultrasound, – Image artifacts – MRI safety. Principal of FMRI (functional magnetic resonance imaging), MR spectroscopy, MRI contrast, Limitations and uses of MRI. Configuration of machines available, PET/MRI fusion problems and solutions.
- **Radiological Instrumentation - CT scanner**  
Discovery - Production - Properties of X-rays, basic requirements for diagnostic tubes, Classification of tubes, Physical Principle of X Ray Diagnosis, density, contrast, detail and definition of radiographs, selection of kV, mAs, filtration, FSD, screens, films, grids, contrast media, basics of radiography, fluoroscopy, film/CR/DR systems, image intensifiers, optimisation of patient dose, Filters, Measurement of kV and mAs, CT detectors, CT acquisition, CT reconstruction, CT attenuation correction, CT dose index, dose length product, Radiation dose, CT-PET fusion, Quality Control of CT, Scanner design, Spiral Computed Tomography, Difference between conventional single slice, multislice, spiral and electron beam CT. Comparison of patient radiation doses and effects of slice thickness.

Mamography, bone densitometry, dental radiography, interventional radiology, digital radiology,

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Quality Assurance (QA) in all modalities of diagnostic radiology, workload planning radiation protection survey and regulatory aspects of diagnostic radiology.

▪ **Advanced Molecular Imaging**

Optical, Molecular, Positron Emission Mammography: (Basic principles, Instrumentation)

▪ **Contrast Agents**

Contrast media agents: Oral, IV – ionic/non-ionic, Rectal, Intrathecal, Catheters, Types/indication/chemical makeup etc. Iodinated contrast materials, Characteristics of iodinated contrast materials, Water solubility and hydrophilicity, Osmolality, High osmolar contrast media (HOCM), Low osmolar contrast media (LOCM), Advantages of LOCM, Disadvantages of LOCM, Viscosity, Calcium binding, Iodine concentration, Adverse reactions. Substitution of barium- based contrast instead of iodinated oral contrast, Indications for steroid premedication, Contraindications for steroid premedication.

**Course Outcomes:**

- Understand functioning of imaging & non-imaging Nuclear Medicine instruments, their quality control, and application, viz. rectilinear scanner, gamma camera, SPECT, PET-CT, uptake probe, gamma probe, whole body counter, dose calibrator and radiation monitoring instruments. complimentary imaging devices such as
- USG, CT & MRI. Recent advances in SPECT, PET, developments in detector systems including hybrid systems such as PET-MRI.
- Acquire knowledge of diagnostic in-vitro techniques for detection of various drugs, hormones, or microbes using RIA, IRMA, Radio respirometry, Radioreceptor assay, and other Immunoassays and quality control of these procedures.
- Understand and apply knowledge about non-imaging techniques using radionuclides.
- Understand and apply knowledge in patient preparation & instruction, interventional approaches, selection/choice of -radiopharmaceuticals and its dose, equipment, -imaging techniques, & imaging parameters for various nuclear medicine procedures. Learn specific techniques applied for various organ imaging, tumour imaging, lymphoscintigraphy, sentinel node scintigraphy, infection and inflammation.
- Learn and apply techniques in Image processing and recording, image display & report generation. To enable skilful application of gained knowledge in performing quantitative data analysis.
- Pre therapy workup and post therapy imaging.

## HLTH20-607: Cyclotron Operation for Routine Isotope Production (42 Lecture)

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### Course Details:

#### ▪ Particle accelerators

Physics of Charged Particle accelerators, Electrostatic Accelerators, Linear Accelerators, current linacs, Cyclotron and its types (Positive ion, Negative ion, Azimuthally and Sector Focussed), current cyclotrons, Synchrotron, Beamlines on Indian Synchrotron Radiation Source Indus-1 and Indus-2, Isochronous Cyclotron, Microtron, Betatron,

#### ▪ Medical Cyclotron

Different accelerators used for isotope production, what is medical cyclotron? RF frequency, magnets, beam focusing and extraction, target design. Target types (internal, external), Application of physics to targetry (Interactions of charged particles with matter, Stopping power and ranges, Energy straggling, Small angle multiple scattering) Application of chemistry to targetry (Chemical interactions in the target, Specific activity and contaminants in the target material, Target temperatures, Radiation damage), Application of engineering to targetry (Heat transfer, Target window foil materials, Target body materials density with inclined planes), Beam transport, Collimators, Beam focusing, Wobbling and rastering, Beam profile monitoring.

#### ▪ Electronics related to accelerators

Voltage and current regulation principle, Oscillators, Overvoltage and overcurrent Protection, Use of Multimeter, Oscilloscope and Spectrum Analyzer

#### ▪ Theory of radioisotope production

Introduction, Nuclear reaction model, Compound nuclei, Energetics of Nuclear Reactions, Kinematics, Q value, Projectiles for Nuclear Reactions, threshold energy, Cross Sections of Nuclear Reactions, Yield of Nuclear Reactions, Production rates and cross-sections, Saturation factors and practical yields

#### ▪ Cyclotron Instrumentation and Subsystems

Magnet Power Supply, Principles of RF generation and measurement, Extraction System, Targetry (Solid, Liquid and Gas), advantages and limitations, Target Maintenance, Cooling Systems, Transmission Lines, Ion Sources, Vacuum Pumps, Vacuum Gauges, Temperature transducer and loops, Pressure Measurement, Flow measurement, Conductivity and humidity measurement, Air compressors, Linear and Rotary Motion Transducers, Feedback Control Systems

#### ▪ Production of medically useful radioisotopes in Cyclotron

Choice of an accelerator, Comparison of cyclotrons with other accelerators, Radioisotope yield considerations, Characteristics of commercial cyclotrons, Operating costs, Maintenance.

##### • PET isotopes

Production  $^{18}\text{F}$ ,  $^{11}\text{C}$ ,  $^{13}\text{N}$ ,  $^{15}\text{O}$ ,  $^{68}\text{Ga}$  using liquid targets, production other PET isotopes ( $^{124}\text{I}$ ,  $^{86}\text{Y}$ ,  $^{89}\text{Zr}$  etc) using solid and gaseous targets

##### • SPECT isotopes

$^{67}\text{Ga}$ ,  $^{201}\text{Tl}$ ,  $^{123}\text{I}$ ,  $^{111}\text{In}$ ,  $^{64}\text{Cu}$ ,  $^{103}\text{Pd}$ . Production, separation & purification

- **Therapeutic isotopes**

Alpha emitters  $^{211}\text{At}$ ,  $^{225}\text{Ac}$

- **Cyclotron Operation and maintenance**

Responsibility of Cyclotron Operator, Safety Regulations and Guidelines, Safety Checks, Checklists and Recordkeeping, Machine and Personnel Safety Interlocks, Cyclotron Shielding Principles, Radiation Detection and Monitoring in Cyclotron, Waste Management (Liquid, Solid and Gaseous Waste), Gas supplies and other Consumables

- **Cyclotron produced generators.**

$^{68}\text{Ge}/^{68}\text{Ga}$ ,  $^{82}\text{Sr}/^{82}\text{Rb}$ ,  $^{81}\text{Rb}/^{81\text{m}}\text{Kr}$ ,  $^{83}\text{Rb}/^{83\text{m}}\text{Kr}$

- **Applications of Accelerators**

Industry, Healthcare, Food & agriculture, Material Science, Bioscience, Accelerator Driven system (ADS) for nuclear power programme  
Tutorial

- **Tutorial**

**Course Outcomes:**

- Learn and apply knowledge of Principle and functioning of Medical Cyclotron. Cyclotron instrumentations and its subsystems. Radiation safety associated with medical cyclotron. Isotope production in cyclotron. Production of generators using. Routine cyclotron operation and maintenance. Other application of accelerators

## HLTH20-608: PET Radiochemistry & Radiopharmacy (30 Lecture)

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### Course Details:

- **PET radionuclides used in nuclear medicine**

What is PET, Advantages of PET, Characteristics of different PET radioisotopes used in NM, Specific radiochemical considerations, Specific radio pharmacological considerations, Ideal Positron-Emitting Radionuclide.

- **PET radiopharmaceutical**

What is a PET radiopharmaceuticals, The role of radiopharmaceuticals in PET, Advantages of PET over SPECT, Vehicle molecules, Pharmacological prerequisites for PET ligands, Development of PET-Radiopharmaceuticals: Biochemical Basis, PET tracers mainly reflecting energy utilization, Glucose Metabolism: [ $^{18}\text{F}$ ]FDG, Bone Metabolism: [ $^{18}\text{F}$ ]Fluoride, Proliferation markers, [ $^{18}\text{F}$ ]Fluorothymidine (FLT), Membrane Lipid Synthesis: [ $^{18}\text{F}$ ]Fluorocholeline (FCH) and  $^{18}\text{F}$ -Acetate, Amino Acid (AA) Transport and Protein Synthesis: [ $^{18}\text{F}$ ]FDOPA, PET tracers for tumor hypoxia: [ $^{18}\text{F}$ ] Fluoromisonidazole (FMISO),  $^{18}\text{F}$ -FAZA, Estrogen Receptor Binding: [ $^{18}\text{F}$ ]Fluoroestradiol (FES), Specific target interactions (enzymes, transporters, receptors),  $^{68}\text{Ga}$ -DOTA peptides,  $^{68}\text{Ga}$ -PSMA and other  $^{68}\text{Ga}$  PET RPhs. Other important PET tracers. The Role of FDA, Current Good Manufacturing Practices (CGMPs)

- **Radiochemistry of  $^{18}\text{F}$ -Labeled Radiopharmaceuticals**

HOT cell, Handling of gaseous radioisotopes, Synthesis Modules and Automation in the synthesis of PET RPhs, Micro-reactors for PET Tracer Labelling,  $^{18}\text{F}$  Labelling methods, Details of steps involved in general nucleophilic radio fluorination,  $^{18}\text{F}$  labelling of small molecules,  $^{18}\text{F}$ -labelling of Peptides and Proteins, microwaving in  $^{18}\text{F}$  Chemistry, Radio synthesis of,  $^{18}\text{F}$ -Fluorodeoxyglucose (FDG),  $^{18}\text{F}$ -Fluorodopa,  $^{18}\text{F}$ -Fluorothymidine (FLT),  $^{18}\text{F}$ -MISO,  $^{18}\text{F}$ -FAZA,  $^{18}\text{F}$ -FET,  $^{18}\text{F}$ -FBA,  $^{18}\text{F}$ -NaF,  $^{11}\text{C}$ -Sodium Acetate,  $^{13}\text{N}$  $\text{H}_3$  and  $\text{H}^{15}\text{O}$ . n- $^{15}\text{O}$ -Butanol,  $^{13}\text{N}$ -Ammonia,  $^{11}\text{C}$ -Sodium Acetate,  $^{11}\text{C}$ - Flumazenil,  $^{11}\text{C}$ -L-Methionine,  $^{11}\text{C}$ -Raclopride

- **Radiochemistry of  $^{68}\text{Ga}$ -Labeled Radiopharmaceuticals**

Generator Production of  $^{68}\text{Ga}$ , performance parameters of  $^{68}\text{Ge}/^{68}\text{Ga}$  generators,  $^{68}\text{Ge}$  breakthrough, different  $^{68}\text{Ge}/^{68}\text{Ga}$  column generators, Coordination chemistry of Ga,  $^{68}\text{Ge}/^{68}\text{Ga}$  Generator Eluate Quality and Subsequent Labelling Chemistry, different methods of purification of  $^{68}\text{Ga}$ , different methods of  $^{68}\text{Ga}$  radiolabelling, role of buffers in radiolabelling, stability of Ga complexes, radio-synthesis of  $^{68}\text{Ga}$ -PSMA,  $^{68}\text{Ga}$ -DOTA peptides and other  $^{68}\text{Ga}$  based RPhs.

- **Radiochemistry of other PET Radiopharmaceuticals**

$^{82}\text{Rb}$ -Rubidium Chloride,  $^{13}\text{N}$  $\text{H}_3$ ,  $^{11}\text{C}$  based PET RPhs

- **QC of PET radiopharmaceuticals**

Parametric release. Physicochemical Tests, Biological Tests, Pharmacopeia specifications for Routine PET Radiopharmaceuticals. QA of PET radiopharmaceuticals by TLC scanner, HPLC and gas chromatography (GC).

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▪ **Development of animal models for biomedical research**

- **Animal models in field of Biomedical research with emphasis on Nuclear Medicine**  
What is an animal model, why animal model, different types of model and strains, purpose of animal model, alternative to animal model, its application in different field majorly in Nuclear Medicine, Small animal transgenic techniques?
- **Ethical guideline for animal experiments and animal biodistribution, pharmacokinetic studies by using Nuclear Medicine techniques**  
Regulatory guideline of CPCSEA, animal cruelty act in India, IAEC, Experiment approval procedure, Definition of animal biodistribution, aim, requirement, procedure, interpretation, safety precautions, pharmacokinetic procedure by using PET-CT imaging

**Demonstrations**

1. Biodistribution of radiolabelled radiopharmaceuticals in animals
2. Animal Imaging

**Course Outcomes:**

- Understand and apply knowledge of use of different PET radioisotopes in nuclear medicine. Different PET
- Radiopharmaceuticals used in NM.
- Advantages of PET RPs. Radiochemistry of different positron emitting radioisotopes labelled RPs. QC of PET RPs. Animal models in field of Biomedical research with emphasis on Nuclear Medicine. Ethical guideline for animal experiments and animal biodistribution, pharmacokinetic studies by using Nuclear Medicine techniques
- Learn and apply the concept of automation in 18-F Radiopharmacy. Different types of automation. Automated synthesiser and dispenser. Waste gas decay system.

## HLTH20-609: Application of RPhs in Clinical medicine (47 Lecture)

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**Dr. Shrinibas Nayak,**  
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### Course Details:

#### ▪ **Thyroid studies**

Anatomy and Physiology of thyroid, RPhs for thyroid studies, Diagnostic agents:  $^{131}\text{I}$  NaI - Capsules and Solutions,  $^{99\text{m}}\text{TcO}_4^-$ , Thyroid imaging and uptakes ( $^{99\text{m}}\text{Tc}$  and  $^{131}\text{I}$ ), Perchlorate discharge test, T /T suppression test, TSH stimulation test.  $^{131}\text{I}$  whole-body imaging. Post Therapy Scans. Therapeutic agents:  $^{131}\text{I}$  NaI

#### ▪ **Lung imaging studies**

Anatomy and Physiology, RPhs for Lung imaging, Ventilation studies, Ventilation lung imaging studies using gases ( $^{133}\text{Xe}$ ,  $^{81\text{m}}\text{Kr}$ ), Inhalation imaging using aerosols, aerosols generators, mucociliary clearance, COPD, Pulmonary permeability using DTPA, perfusion studies, perfusion imaging using MAA, Microsphere, and pulmonary embolism.

#### ▪ **Liver-spleen imaging**

Anatomy and Physiology, Liver imaging RPhs, Liver imaging for Diffuse and Focal liver diseases, Dynamic Liver studies, Quantitative methods for Hepatic Perfusion Index, Blood pool liver studies. portosystemic shunt evaluation by Per-rectal Scintigraphy.

#### ▪ **Hepatobiliary imaging**

RPhs for hepatobiliary imaging,  $^{99\text{m}}\text{Tc}$ - HIDA derivatives,  $^{99\text{m}}\text{Tc}$ - Disofenin,  $^{99\text{m}}\text{Tc}$ - Mebrofenin Hepatobiliary imaging protocols, Neonatal hepatitis versus Biliary atresia, Gall bladder dynamic studies using IDA compounds. Deconvolution analysis, Hepatic Extraction Fraction, Interventional methods. Bile leak studies.

#### ▪ **Gastrointestinal studies**

Conventional imaging modalities used for GI studies. Advantages and disadvantages of these modalities over scintigraphy. Oesophageal transit time studies, Gastric oesophageal reflux, gastric emptying time, Duodena-gastric reflux, Meckel's diverticulum imaging, GI bleeding with  $^{99\text{m}}\text{Tc}$ -RBC,  $^{99\text{m}}\text{Tc}$ -S. Collide. Advantages and disadvantages of each method

#### ▪ **Cardiac studies**

RPhs for heart imaging, Perfusion Imaging:  $^{201}\text{Tl}$ ,  $^{99\text{m}}\text{Tc}$ - MIBI,  $^{99\text{m}}\text{Tc}$ - Tetrathosmin,  $^{82}\text{Rb}$  Chloride,  $^{13}\text{N}$  Ammonia, Metabolic Imaging:  $^{18}\text{F}$  FDG,  $^{13}\text{N}$  Amino Acid (GLUTAMIC ACID), Myocardial Infarct Imaging :  $^{99\text{m}}\text{Tc}$  -PPi, ECG, First pass study (shunt detection), Importance of Electrocardiogram (ECG), gated blood pool study, MUGA, Ejection fraction, Wall motion analysis, Infarct avid imaging, Rest / Stress myocardial imaging, Gated SPECT, Pharmacological stress, Bulls Eye analysis, Severity scores. Use of  $^{201}\text{Tl}$ ,  $^{18}\text{F}$ FDG and  $^{13}\text{NH}_3$  for cardiac studies.

#### ▪ **Bone imaging**

Bone imaging agents  $^{85}\text{Sr}$ ,  $^{87\text{m}}\text{Sr}$ ,  $^{99\text{m}}\text{Tc}$ - PPI,  $^{99\text{m}}\text{Tc}$ - HEDP,  $^{99\text{m}}\text{Tc}$ -MDP, Routine bone (whole

body and spot) imaging, bone flow study, quantitative bone scan-sacroiliac index, 3-phase bone scans, Bone SPECT. Bone imaging in Metabolic Disorders. MDP retention studies, <sup>18</sup>F-Fluoride Bone Scans.

▪ **Renal imaging studies**

Anatomy and Physiology, Renal imaging Agents, GFR Agent: <sup>99m</sup>Tc - DTPA, Iothalamate, Tubular Secretion Agents : <sup>99m</sup>Tc- MAG<sub>3</sub> , <sup>99m</sup>Tc- EC, <sup>131</sup>I OIH, Renal cortical agents : <sup>99m</sup>Tc GHA, <sup>99m</sup>Tc- DMSA, Standard Renogram, Diuretic renogram, Captopril renogram, Renal Perfusion analysis, Differential function, GFR estimation by Gates Method, Renal transplant studies, Background subtraction methods, Rutland Patlak-Plot, Plasma Sampling methods, Advantages and Disadvantages of various GFR estimation methods, Uretic reflux study, Interventional methods, Direct and indirect radionuclide cystourethrography, Cortical Renal Scans using <sup>99m</sup>Tc-GHA & <sup>99m</sup>Tc-DMSA, Differential function by Geometric Mean.

▪ **Brain imaging**

Anatomy and Physiology, RPS for brain Imaging – Non diffusing Agents: <sup>99m</sup>TcO<sup>-</sup> , <sup>99m</sup>Tc-DTPA, <sup>99m</sup>Tc- GH, Diffusing Agents: <sup>123</sup>I –HIPDM, <sup>99m</sup>Tc- HMPAO, <sup>99m</sup>Tc- ECD, metabolic agents: <sup>18</sup>F FDG, Cerebral blood flow dynamic studies, Blood Brain Barrier imaging, Perfusion Imaging, Brain SPECT, Interventional methods, Cisternography, CSF leak, PET brain imaging.

▪ **Tumour Imaging**

<sup>18</sup>F-FDG PET Scans for Oncologic Staging and Evaluation of Post therapy status. Imaging for Medullary Carcinoma of Thyroid, Neural Crest Tumours, Apoptotic Imaging. Post Therapy Scans. Organ specific (cold spot, hot spot), nonspecific (<sup>67</sup>Ga- Citrate, <sup>201</sup>Tl, <sup>131</sup>I MIBI, <sup>99m</sup>Tc

Tetrofosmine, <sup>18</sup>F-FDG), Tumor type specific (<sup>131</sup>I for papillary and follicular carcinoma, <sup>131</sup>I mIBG (adrenal cortex), NP59 for adrenal medulla, <sup>99m</sup>Tc Mebrofenin for hepatocellular ca, Antibody (<sup>111</sup>In Oncoscint, <sup>99m</sup>Tc CEA, <sup>111</sup>In Proscint, <sup>99m</sup>Tc-Verluma, peptide (<sup>111</sup>In Octreotide, <sup>68</sup>Ga DOTATATE) <sup>99m</sup>Tc-HYNICTOC

▪ **Gastrointestinal studies**

Conventional imaging modalities used for GI studies. Advantages and disadvantages of these modalities over scintigraphy. Oesophageal transit time studies, Gastric oesophageal reflux, gastric emptying time, Duodena-gastric reflux, Meckel's diverticulum imaging, GI bleeding with <sup>99m</sup>Tc-RBC, <sup>99m</sup>Tc-S. Collide. Advantages and disadvantages of each method

▪ **Other Imaging Studies**

• **Lymphoscintigraphy & Sentinel Node Scintigraphy**

• **Infection and inflammation**

Use of Labelled Leukocyte, <sup>99m</sup>Tc-Ciprofloxacin, <sup>68</sup>Gallium for detection of Infectious foci. Discussion of imaging preferences.

• **Salivary gland imaging**

Imaging for parenchymal and obstructive diseases of salivary glands. Post Radiation Xerostomia evaluation.

• **Parathyroid Imaging**

Dual isotope technique and Subtraction scans.  $^{99m}\text{Tc}$ -MIBI wash out studies.

- **Bone marrow imaging**

Imaging techniques for visualisation of Bone marrow infiltration

**Course Outcomes:**

- Understand and apply principles of Clinical Nuclear Medicine for diagnosis and treatment of various diseases encompassing Oncology, Cardiology, Nephrology, Endocrine disorders, Neurology and Skeletal Systems. Organ specific studies.

## HLTH20-610: Recent advances in Radio pharmacy (30 Lecture)

Coordinators: Dr Mukti Kanta Ray  
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### Course Details:

#### ▪ **Nanotechnology**

Concepts and its biomedical applications, liposomes, aerosols, nanoparticles, immuno-liposomes, drug delivery systems. Introduction to Nanotechnology and their application in nuclear medicine for diagnostic and therapeutic purposes. Different types of drug delivery nanocarriers for diagnostic and therapeutic purposes (Liposomes, micelles, phytosomes, Chitosan Nanoparticles etc.) and their advantages over present drug delivery systems. Methods of preparation of Nanocarriers and quality control procedures. Mechanism of localisation of nanodrug delivery systems. Future applications in Nuclear Medicine.

#### ▪ **Theranostic and Personalized NM**

Concept and prospects of theranostic in nuclear medicine. Theranostic radiopharmaceuticals, Personalized Nuclear medicine, Theragnosis in personalizing treatment & regime. Different theranostic radioisotopes used in nuclear medicine. Theranostic in the treatment of neuroendocrine tumor. Theranostic in the treatment of prostate cancer. Targeted radiotherapy: Radioimmunotherapy (Rituximab). Antibodies, antigens, RIT- Advantages of RIT, selection of Antibodies & antigens treatment of non-Hodgkin's, B-cell lymphoma Peptide Receptor Radionuclide Therapy: Introduction, amino acids, peptides, proteins, PRRT for NET- PRRT studies with

[<sup>111</sup>In- DTPA]- octreotide, Somatostatin receptor Radiotherapy -with <sup>90</sup>Y-DOTATA TOC, <sup>90</sup>Y- DOTA TATE, and <sup>177</sup>Lu-DOTA TATE, Bombesin peptides analog, ViP analog, CCK analog, neurotensin peptide analog. PRRT for prostate cancer with <sup>177</sup>Lu- PSMA.

Radionuclide administration techniques, pre and post therapy precautions, nursing care, patient monitoring and discharge criteria, optimization of radiation dose to non target tissues, radiation safety consideration in treatment of various types of Radionuclide therapy practised such as Thyroid disorders and Thyroid Cancer, PRRT, palliative care radiation synovectomy and other diseases.

#### ▪ **Molecular Imaging probes**

Target specific radiopharmaceuticals 6 lectures Basics of molecular imaging, methodology of molecular imaging, Classification of radiopharmaceuticals, blood flow/membrane transport radiopharmaceutical, metabolism-based radiopharmaceutical. Receptor & transport mediated radiopharmaceutical. Receptors, receptor binding, design of radiopharmaceutical, bifunctional approach, chelating agents, radiolabeling, Ideal radiopharmaceutical, Various receptor imaging agents SSTR, Bombesin, Vasoactive intestinal peptides,  $\alpha$ -Melanocyte-Stimulating Hormone, Neurotensin, Substance P (SP), Cholecystikinin (CCK), Neuropeptide Y (NPY) reporter genes for imaging.

#### ▪ **New development in therapeutic agents**

Nano technology based therapeutic agents, Liposomes, Therapeutic Radiopharmaceuticals for Bone Pain Palliation: Introduction, commercial agents <sup>186</sup>Re-HEDP, <sup>89</sup>SrCl<sub>2</sub>, <sup>153</sup>Sm-EDTMP, New

Agents -  $^{188}\text{Re}$ -HEDP,  $^{188}\text{Re}$  (V)DMSA,  $^{177}\text{Lu}$ - EDTMP.

- **Radioimmuno scintigraphy & therapy**
- **Radionuclide Synovectomy: Introduction, Advantages, Selection of RN**
- **Radiopharmaceuticals for treatment of primary and metastatic Hepatic Cancer**
- **Balloon therapy**
  
- **Introduction to Bio-molecular Modelling**  
Introduction of Molecular Modelling-Protein structure prediction-Structure-based drug design-Docking-Virtual Screening-Molecular Dynamics-Protein folding prediction-Ligand-based drug design(CoMFA, CoMSIA, HypoGen)- Scoring functions and weight rules.
  
- **New Development in Cyclotron and Radiochemistry Modules**  
ECR ion sources, Super Conducting Cyclotrons, Hadron Therapy, Boron Neutron Capture Therapy, Microfluidics based Radiochemistry

**Course Outcomes:**

- Provide exposure to advanced experimental/theoretical methods and train in research and life-long learning to adapt to the changing environment.
- Learn and apply the concept of theranostics and its application in personalising NM. Target specific radiopharmaceuticals. Application of nanotechnology in NM. Newer developments in medical cyclotron and radiochemistry modules. Bio-molecular modelling.

## **HLTH20-611: Layout planning and Regulatory Aspects of MCF and RP Labs (30 Lecture)**

**Coordinators: Dr Mukti Kanta Ray**  
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**Dr. Shrinibas Nayak,**  
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### **Course Details:**

- **Radiation safety in NM - Regulatory Aspects 10 Lectures**
  - Layout of Nuclear Medicine Laboratory
  - Design of radiation labs, types of labs
  - Security of Sources and radioactive cautions signs and labels.
  - Relevant regulatory documents, Such as Acts Rules Code, Standard and Guides; The Atomic Energy Act, Rules issued under the Act, Surveillance procedures issued under the Rules
  - Notifications issued under RPR, 2004
  - AERB Safety Directive, Safety code for NM facility
  - Duties of RSO, responsibilities for implementation of Basic Safety Standards Requirements; responsibilities of employer, licensee, RSO, technologist and radioisotope supplier.
  - Regulatory Clearance-Approval of NM Lab, Physician & RSO
  - Regulatory consent, authorisation- for disposal of radioactive waste and safe transport of Radioactive materials. Regulatory requirements for import/export, procurement use handling transfer and disposal of radioisotope; inventory control
  - Safety and security of radioactive sources, inventory control, security provisions, administrative and technical measures, graded approach in security provision, physical protection system
  - Radiation Safety Program&Radiation protection program (RPP)
  - Radiation Safety Committee
  - Guidance level for diagnostic administration, misadministration and preventive measures, reporting of misadministration.
  - Radiation emergency in NM and preparedness: Normal and potential exposures accident situations involving radioisotopes, elements of emergency planning and preparedness including procedures for notification and communication, administrative and technical procedures, emergency response accessories, responsibilities of employer, licensee, RSO technologist and radioisotope supplier in case of emergency.
  - Radiation Accidents case studies and Lessons Learned:Radiation accidents involving radioisotopes, orphan and vulnerable sources, handling of emergency situations resulting from spillage of radiopharmaceuticals/liquid radioisotopes, misadministration of radiopharmaceuticals and its consequences, general methods of prevention of accidents, loss of radioisotope, fire accidents and explosions, follow up actions through emergency response plans, case studies and mitigation, lessons learned.
  
- **Layout planning of Radio pharmacy laboratory and Nuclear Medicine facility**

Classification and general features of NM laboratories and RP preparation facility. ( site, typical floor plans ventilation, surface walls, floor and ceiling, work surfaces, containment systems, fume hoods, glove box)

Regulatory requirements, pharmaceutical aspects, radiation safety aspects, local constraints, design

of hospital pharmacy, stocking of consumables and labels, disposable materials. Laminar airflow (LAF) hood, its testing and maintenance.

Centralized Nuclear Pharmacy, considerations & layouts. Automated Modules *vis a vis* Medical Cyclotron facility, PET-CT/PET-MRI, Spect, Spect-CT, and Radionuclide Therapy wards

Licenses and procurement of radiopharmaceuticals. Trace of delayed shipments, surveys, wipe tests, packaging, disposal, storage requirements, and record keeping logs.

▪ **Regulatory Requirements and Guidelines for Medical Cyclotron Facility**

Consenting process, medical cyclotron facility design: self-shielded vs bunker-design; safety interlocks for gamma and neutron radiations; Steps to minimize activation of various components, operation and maintenance, roles and responsibilities (Employer, Licensee, Radiological Safety Officer, Radiation Workers, Student/Trainee, Medical Cyclotron Operators, Radiochemist), Unusual Incidences & Reporting, operational radiation protection, labelling, marking, packaging and distribution, security aspects, emergency preparedness, decommissioning. Staff requirement for Medical Cyclotron Facility and their qualifications. AERB guidelines, requirement and procedure for setting up of Medical Cyclotron, protective and Emergency equipment requirements in medical cyclotron facility.

▪ **New Regulatory aspects of Radiopharmaceuticals**

Radiation Regulations for Radiopharmaceuticals, Role of RPC, Role of DCGI, GMP aspects of Radiopharmaceuticals, Rules for importing and exporting RPhs(AERB).

▪ **Documentation**

Record keeping of RPhs, transporting of radioactive materials, radiation surveillance records, personal dose records, unusual incidence reporting/recording.

**Course Outcomes:**

- Learn and apply radiation protection measures in diagnostic and therapeutic Nuclear Medicine. Learn protection of patient, regulatory aspects like layout planning of RP laboratory, patient discharge limits, AERB directives for dose limits, Safety Code, Duties of RSO. Regulatory Requirements and Guidelines for Medical Cyclotron Facility. Regulatory aspects of Radiopharmaceuticals. Documentation

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## PRACTICALS

### LIST of Practical in Semester II (01-HLTH20-601-P)

#### Course Details:

- To measure Half Value Layer of  $\beta$  and  $\gamma$  emitters and to measure the absorption coefficients of different materials with gamma rays and beta particles
- To study back scatter.
- To determine the half life of a radioactive material.
- To study the change in activity of a sample consisting of two independently decaying radioisotopes (or a mixture of isotopes)
- To determine the plateau of GM tube and find out the dead time/ resolving time of GM counter.
- To determine the efficiency of GM counter and find out the activity of the given unknown radioactive source.
- Gamma ray spectrometry of  $^{137}\text{Cs}$  with a single channel analyzer
- To find out the spectrum of energies emitted by a radioisotope by using gamma ray spectrometer. (e.g.  $^{131}\text{I}$ )
- To study the statistics of radioisotope measurements and observe the effect of background on the counting statistics.
- To determine the energy resolution of spectrometer
- To study the energy linearity of given spectrometer
- To observe gamma ray spectrum of the given two radionuclide sources (A and B) and identify composition of a tube containing mixture of these two radionuclide sources by evaluating scatter fraction.
- To identify unknown radionuclide on the basis of its principal energy by using scintillation counter.
- To perform quality control of Dose Calibrator.
- Radiopharmacy procedure: Elution of generators and calculation of labelling efficiency.
- To prepare  $^{99\text{m}}\text{Tc}$  labeled radiopharmaceuticals involving the use of a single and a double vial preparation
- Determination of  $^{99\text{Mo}}$  breakthrough in  $^{99\text{m}}\text{Tc}$
- Q.C. of radiopharmaceuticals by paper chromatography & to determine the  $R_f$  of  $^{99\text{m}}\text{Tc}$  and the given labeled compounds by using ascending chromatography.
- Rapid determination of radiochemical purity of radiopharmaceuticals.
- To estimate pipetting error and Estimation of Unknown Volume by Dilution principle.
- Biodistribution study of radiopharmaceuticals. (Demonstration)
- Perform Radioimmunoassay & IRMA.

#### Course Outcomes:

- To study and perform practicals on basic aspects of instruments used in nuclear medicine, including performance evaluation and quality control.
- To study effect of counting statistics and errors in measurements.
- To study characteristics of Geiger Mueller Counters for its application in monitoring and surveillance.
- To understand and perform nuclear medicine procedures including, -patient preparation, - radiopharmaceutical preparation & their quality control, -dose administration, -data acquisition, - data processing, -report generation, and evaluation of these techniques.

## **LIST of Practical in Semester -IV**

### ***Course Details:***

- Radioisotope production in Medical cyclotron
- Radiolabelling of  $^{18}\text{F}$  based RPs (FDG, NaF, FLT, FET)
- Q.C. of PET radiopharmaceuticals by TLC scanner and HPLC
- Radionuclide purity of  $^{68}\text{Ga}$
- Radiolabelling of  $^{68}\text{Ga}$  DOTATATE/PSMA& QC
- Radiolabelling of  $^{177}\text{Lu}$  DOTATATE/PSMA& QC
- Radiolabelling of  $^{90}\text{Y}$  DOTATATE & QC
- Radiolabelling of  $^{225}\text{Ac}$  DOTATATE/PSMA& QC
- Radiolabelling of Antibodies and other peptides
- BIO QC of Radiopharmaceuticals

### ***Course Outcomes:***

- To prepare radiopharmaceuticals in a hospital radiopharmacy setup and to perform their Quality control tests (physicochemical & biological).
- To operate medical cyclotron for isotope production

## Apprentice Program

### *Course Details:*

- **Apprentice Program for first year**

660 hours (roughly ten months of Apprentice in various areas of Nuclear Medicine @3hrs per day)

1. PET, SPECT and SPECT CT for cardiac/bone/ renal/ and other organs anatomic and functional imaging studies.
2. Hospital Radiopharmacy and BIO QC facility:  $^{99m}\text{Tc}$ -Radiopharmaceutical Preparation and its QC,  $^{68}\text{Ga}$ -RP preparation and its QC,  $^{177}\text{Lu}$ -RP preparation and its QC,  $^{90}\text{Y}$ -RP production and its QC, BET and sterility testing; documentation of Production and processes.
3. Radiation Hazard Control Unit, RMC: students to introduced to responsibilities and duties of RSO.
4. MCF facility and PET pharmaceutical preparation facility
5. RIA facility
6. Radionuclide Therapy ward.

- **Apprentice Program for Second year**

1200 hours (roughly ten months of Apprentice in various areas of Nuclear Medicine @5.5 hrs per day)

### *Course Outcomes:*

- To learn and understand the practices adopted in a modern diagnostic and therapeutic nuclear medicine setup by hands-on training. Specialised hands-on training on medical cyclotron operation, radiosynthesis of SPECT, PET and therapeutic RPs and their QC