M.Sc. Nuclear Medicine & Molecular Imaging Technology

Programme Code: HLTH19

Programme Outcome:

- To be able to understand and apply knowledge of radiation detectors and various imaging and non- imaging equipments like Uptake probe, Gamma Camera, SPECT, PET, Intraoperative Probes in a nuclear medicine laboratory. Role and application of complimentary imaging devices such as USG, CT & MRI.
- To introduce and train on concepts of radionuclide generators and medical cyclotron, radiopharmacy techniques and understand the invivo kinetics of radiopharmaceuticals used in imaging and therapy.
- To understand quality control of instruments and radiopharmaceuticals. To understand and adopt appropriate quality assurance practices in delivery of nuclear medicine services.
- To be able to assume responsibility as Nuclear Medicine Physicist, Imaging Technologist, Radiopharmacist and give orientation to function as Radiation Safety Officer.
- Basic knowledge in biology, biochemistry, physics, and mathematics required for nuclear medicine and its applications.
- Knowledge of patho - phycological conditions in nuclear medicine.
- Familiar with hospital ethics and patient care required in nuclear medicine.
- Knowledge of imaging and non-imaging instruments, data collection and analysis for nuclear medicine applications.
- Knowledge on radiochemistry and radiopharmaceuticals for nuclear medicine applications.
- Advanced knowledge on practical aspects of computer hardware and programming required in nuclear medicine.

DETAILED COURSE STRUCTURE

		LIST of COURSES			
Semester	**Course Code**	**Course Code**	**Subject Title**	**Lectures (Hours)**	**Marks**
Semester I	PAPER-1	01-HLTH19-601-C	Physical sciences for Nuclear Medicine	43	100
	PAPER-2	01-HLTH19-602-C	Chemical sciences for Nuclear Medicine	32	100
	PAPER-3	01-HLTH19-603-C	Biological sciences for Nuclear Medicine	42	100
Semester II	PAPER-1	01-HLTH19-604-C	Radiation Physics, Radiation Biology & basics of Radiation protection	34	100
	PAPER-2	01-HLTH19-605-C	Diagnostic and therapeutic Radiopharmacy and quality control	44	100
	PAPER-3	01-HLTH19-606-C	Non imaging Nuclear Medicine Instruments & quality control	31	100
	PRACTICAL I	01-HLTH19-601-P	Radiation Protection Instruments and Quality Control		50
	PRACTICAL-II	01-HLTH19-602-P	Radiopharmacy, Invitro and Non-imaging Techniques		50
Semester III	PAPER-1	01-HLTH19-607-C	Radiation Protection and In-vitro & non imaging Nuclear Medicine Techniques	43	100
	PAPER-2	01-HLTH19-608-C	Nuclear Medicine Imaging Instruments & quality control	33	100
	PAPER-3	01-HLTH19-609-C	Recent advances in nuclear medicine & correlative, molecular imaging	43	100
Semester VI	PAPER-1	01-HLTH19-610-C	Clinical Nuclear Medicine Techniques part I	43	100
	PAPER-2	01-HLTH19-611-C	Clinical Nuclear Medicine Techniques part II	44	100
	PRACTICAL - III	01-HLTH19-603-P	Methods in radiation protection and quality control of instructions		50
	PRACTICAL-IV	01-HLTH19-604-P	Clinical Nuclear Medicine Techniques		50
	VIVA VOCE	Grand Via Voice	ViVa-Voice, Apprentice Program Seminar, Dissertation		100
			GRAND TOTAL		1400

DETAILED SYLLABUS

HLTH19-601: Physical sciences for Nuclear Medicine (43 Lecture)

Coordinators: Dr.Sushma Awasare
sawasare@barc.gov.in
Dr. Biju Menon,
bmenon@barc.gov.in

Course Details:

- **Basic 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.

- **Basic 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.

- **Origin & Types of Radiation**
  Fundamental constituents (quarks, leptons) and interactions of matter according to the "Standard Model", Properties of Nuclear Forces, Stability of nuclides - binding energy forces and nuclear forces, Spin, electric and magnetic moments, Laws of radioactivity, Units of radioactivity. Decay modes, Stability of atom, Mass defect, Binding energy, The basis of radioactivity (N/Z ratio). Types of radioactivity depending on N/Z ratio Types of radiation (□, □, □, X-ray, n). Theory of gamma decay, radionuclide chart, Laws of successive transformations, 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.

Course Outcomes:

- Understand and strengthen concepts of basics of -electronics, -mathematics and statistics related to nuclear medicine.
- Learn origin and types of radiation

References Books:

1. Patwardhan B., Desai A., Chourasia A, Nag S., Bhatnagar R. 2020. Guidance Document: Good Academic Research Practices. New Delhi: University Grants Commission.
2. Cook, Claire Kehrwald. (1986) Line by Line: How to Edit Your Own Writing. Miffin Company, Houghton
3. Mertens, D. M., & Ginsberg, P. E. (2009). The handbook of social research ethics, Thousand Oaks, CA, SAGE Publications, Inc., doi: 10.4135/9781483348971
4. Research Methodology (The Aims, Practices and Ethics of Science) by Peter Pruzan
5. P. Corbetta, Social Research - Theory, Methods and Techniques, 2003, London: Sage
6. Writing Scientific Research Articles: Strategy and Steps by Margaret Cargill, Patrick O'Connor
7. Effective Science Communication, A practical guide to surviving as a scientist by Sam Illingworth and Grant Allen
8. Beins, B.C. (2004). Research methods: A tool for life. Boston: Allyn& Bacon

HLTH19-602: Chemical sciences for Nuclear Medicine (32 Lecture)

Coordinators: Dr.Sushma Awasare
sawasare@barc.gov.in
Dr. Biju Menon,
bmenon@barc.gov.in

Course Details:

- **Atomic structure & Periodic table**
  Atom and subatomic 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.

- **Chemistry relevant for radiopharmaceuticals**
  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, Chemistry of Heterocyclic Compounds, Catalysts, Physical Chemistry of Macromolecules, ^{99m}Tc-chemistry, Core structures of various common ^{99m}Tc-radiopharmaceuticals, labelling techniques, importance of ^{99m}Tc-kit components, peptide chemistry with respect to ^{68}Ga/^{177}Lu-DOTATOC, DOTA-TATE etc. Principle of radionuclide choice for imaging and therapy with example of ^{68}Ga, ^{177}Lu, ^{90}Y, ^{18}F, ^{99m}Tc etc. Principle of TLC, HPLC with respect to radiochemical purity (RCP).

- **Radionuclides in Nuclear Medicine**
  Radioactive decay, Physical Half-Life, Activity, Decay Constant, Mode of radioactive decay, Alpha particle decay, Beta particle decay, Gamma ray, Requirements for Radiotracers, Radionuclides used in Nuclear Medicine, Radionuclide Considerations, Type and Energy of Emissions, Specific Activity, Radionuclidic Purity, Chemical Properties, Economics, Production of radionuclides, Radiopharmaceuticals, Ideal radiopharmaceuticals, Important characteristics of a radionuclide to be used in imaging.

- **Production of reactor & accelerator produced radionuclides**
  Lectures Successive decay and radioactivity equilibrium, Equation for radionuclide production Reactors and charged particle accelerators. Nuclear reactors: neutron energy and neutron flux, neutron cross section, targets and specific activities, mathematical principles, general radiochemistry. Charged particle accelerators: physics of linear accelerator, cyclotron, synchro-cyclotron, isochronous cyclotron. Medical cyclotron: threshold energy, nuclear cross section, q value, RF frequency, magnets, beam focusing and extraction, target design. Types and makes. Cyclotron produced radionuclides, cyclotron based generator. 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.

- **Development of 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.

- **Modes of localisation**
  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; Receptor Occupancy theory. Application of Differential equations, Open and closed models, Single compartment, two compartment and multicompartment models, reversible and irreversible exchanges, Mammary and Caternary models, Problems on radioactive generators, biological elimination processes of radiopharmaceuticals. Distributed Models.

Course Outcomes:

- Understand and strengthen concepts of atomic structure and periodic table
- Understand and strengthen concepts of chemistry relevant for radiopharmaceuticals
- Understand and learn physicochemical characteristics of radionuclides used in nuclear medicine
- Understand and learn production of radionuclides and development of radiopharmaceuticals
- Understand and learn modes of localization and understand fundamental concepts of compartmental analysis in nuclear medicine.

HLTH19-603: Biological sciences for Nuclear Medicine (42 Lecture)

Coordinators: Dr.Sushma Awasare
sawasare@barc.gov.in
Dr. Biju Menon,
bmenon@barc.gov.in

Course Details:

- **Cell Biology & Cellular Physiology**
  The basic structure of eukaryotic and prokaryotic cell. Different organelles and their function Cell wall, cell membranes. Endoplasmic reticulum, mitochondria, Golgi complex, lysosomes. Nucleus and nuclear membrane and their functions. Transmembrane potential of mitochondria and its implications in transport and intramitochodrial 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, Different cell types of the Immune system, humeral and cell- mediated immune response– primary and secondary responses and their applications, polyclonal and monoclonal antibodies , basic characteristics of antigens and 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, new generation antibodies, Cells & important cytokines, Host versus Graft reactions, host directed immuno therapies, immunobiology of cancer .

- **Biochemistry and Molecular biology**
  Introduction to Biochemistry: carbohydrates, proteins, nucleic acids, enzymes and lipids. Protein structure and its 3-dimensional shape, structure-function relationship, proteins purification, Importance of Amino acids in Nuclear Medicine, Nature of enzyme catalyzed reactions, their regulation, inhibition and mechanisms. Structure and function of carbohydrates and their importance in central metabolism. Metabolism of glucose, acetate, and choline. Importance of Enzymes and their kinetics, Clinical Biochemistry, Structures and nature of fatty acids and lipids found in biological membranes.

- **Introduction to Molecular Biology**
  Nucleic Acids and their function. 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. Vitamins- introduction, functions of vitamins, water soluble and non soluble vitamins, essential and nonessential vitamins, sources of vitamins, deficiencies of vitamins and disease.

- **Introduction to cancer Biology**
  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.

- **Basic Medical Terminology**
  Descriptive – describing shape, color, 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.

- **Introduction 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)**

- **Basic concepts Human Anatomy& Physiology**
  Introduction, definition of anatomy, definition of physiology- musculoskeletal system, cardiovascular system, lymphatic system, respiratory system, gastrointestinal system, hepatobilliary system, genitourinary system, nervous system, endocrine system, receptor system. (Introduction, physiology and pathological conditions)

Course Outcomes:

- Understand and strengthen concepts of general cell biology & cellular physiology, immunology, basic biochemistry, molecular biology, introductory biology of cancer and basic human anatomy and physiology
- Obtain concepts on medical terminology, common hospital practices.

HLTH19-604: Radiation Physics, Radiation Biology & Basics of Radiation Protection (34 Lecture)

Coordinators: Dr.Sushma Awasare
sawasare@barc.gov.in
Dr. Biju Menon,
bmenon@barc.gov.in

Course Details:

- **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.

- **Radiation Quantities and units**
  Exposure, absorbed dose, radiation weighting factor, concept of radiation weighting factor WR, Sievert, equivalent dose, concept of tissue weighting factor WT, effective dose, committed equivalent dose, committed effective dose, 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.

- **Radiation Biology**
  Radiolysis of water, interactions of free radicals, Direct versus indirect effects. 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, DNA, Protein and Lipid, cell membrane, Radiation effects on cell cycle and 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.
  Acute radiation effects: Acute radiation syndrome (ARS), Radiation effects on major organ systems: hematopoietic system, digestive system, reproductive system, nervous system.
  Linear Energy Transfer (LET), Relative biological effectiveness (RBE), Dose rate effect, acute and chronic irradiation, factors influencing radiation response - oxygen concentration, Temperature etc.
  Genetic effect of ionizing radiation: Stochastic and Nonstochastic effects of radiation: Late effects in normal tissue systems and organs, Effects of Ionizing Radiation on the Embryo and Foetus. Teratogenic and delayed effects/long term health effects, Radiation carcinogenesis, radiation induced mutations, 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, Chromosome aberrations, whole body and partial body exposure Extremity dosimetry. Sources of Low Dose Exposure to Ionizing Radiation: Medical, Natural background, Radon exposure, Radiation Hormesis; BERT.

- **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.

- **Transport of radioactive material**
  Classification of radioactive materials, general packing requirements, transport documents, Type of package, Transport Index, Category of package, approval requirements, TREMCARD. Off-normal situation during transport of radioactive materials, surface contaminated objects, handling of off-normal situations, emergency planning, responsibilities of consigner and consignee.

- **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.

- **Tutorials**

Course Outcomes:

- Understand and apply radiation biology, personnel monitoring devices, radiation protection & dosimetry, radioactive material transport.
- Understand and apply Interaction of radiation with matter, radiation quantities and units.
- Understand and apply statistics of counting.

HLTH19-605: Diagnostic and Therapeutic Radio pharmacy and Quality Control (44 Lecture)

Coordinators: Dr.Sushma Awasare
sawasare@barc.gov.in
Dr. Biju Menon,
bmenon@barc.gov.in

Course Details:

- **Generator produced Radionuclides**
  Need for Generator, Advantages of generator system, Definition, Properties of Ideal Generator, Basic Principle, Principles of generator system, Parent Daughter Growth –Decay Relationship, Parent Daughter Equilibrium, Transient Equilibrium, Secular equilibrium. Various generator systems.

  - Gamma emitting radionuclidic generators: ^{99}Mo - ^{99m} Tc, ^{113}Sn – ^{113m}In, Special emphasis on ^{99}Mo - ^{99}m 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 radionuclidic generators: ^{188}W -^{188} Re, ^{90}Sr - ^{90}Y, ^{194}Os - ^{194}Ir, ^{132}Te - 132I. Production of parent, decay Scheme, characteristics of daughter radionuclides, generator suppliers, applications of daughter radionuclide.

  - Positron emitting radionuclidic generators: ^{68}Ge – ^{68}Ga, ^{82}Sr - ^{82}Rb : Production of parent, Decay Scheme, Characteristics of Daughter Radionuclide, Various generator suppliers, Applications of Daughter Radionuclide.

  - Alpha emitting radionuclidic generators and Complex Systems: ^{225}Ac - ^{213}Bi, ^{224}Ra/^{212}Pb/^{212}Bi.

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

- **Methods of radiolabeling**
  Definition of a Radiopharmaceutical, ideal Radiopharmaceutical, availability, short effective half-Life, particle emission, decay by electron capture or isomeric transition. High target-to-

nontarget activity ratio.
Design of new Radiopharmaceuticals. General considerations. Factors influencing the design of new radiopharmaceuticals. Methods of radiolabeling. Isotope exchange reactions. Introduction of a foreign label. Labeling with bifunctional chelating agents. Metal Complexes, Biosynthesis/Bioconjugation. Important factors in labelling. Efficiency of the labelling 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: Radioiodinated radiopharmaceuticals**
  Introduction, isotopes of iodine, production of isotopes with physical properties, principle of radioiodination, methods of radioiodination, iodination of organic compounds – Chemistry of Iodine, chemical properties, oxidation, methods to minimize oxidation. Various radioiodinated radiopharmaceuticals –1)^{131}I-NaI, 2)^{131}I- OIH, 3) ^{131}I-Rose Bengal, 4)^{131}I-IMP (n-isopropyl, p-iodo amphetamine), 5)^{131}I-HIPDM (NNN‟- trimethyl,N‟(2-hydroxy,,3-methyl,5-iodobenzyl)1,3propane diamine), 6) 131I-mIBG, 7)131I-Fibrinogen,
  8)^{131}I- lipiodol, 9)^{131}I-19-Iodocholesterol, radioiodination of peptides, proteins, antibodies/monoclonal antibodies, Methods of labelling, Applications, Advantages, Disadvantages, Dose Administration etc.

- **Specific methods of labeling – Technetium labeling**
  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 99mTc: formation of 99mTc- complexes by ligand exchange, structure of 99mTc-complexes, oxidation states of 99mTc in radiopharmaceuticals and kits for 99mTc-labeling-: DTPA, GHA, DMSA, MIBI, MAG3, MDP, phytates, ECD, EC, IDA compounds and Sulfur Colloid. Dextran colloid and labeled particles. Metal chelate and conjugates, 99mTc-tricarbonyl core, 99mTc-nitrido compounds, 99mTc-Hynic- TOC. Kit formulation of radiopharmaceuticals and their classification. Additives, stabilisers, and preservatives. Labelling with 99mTc: formation of 99mTc- complexes by ligand exchange, structure of 99mTc-complexes, oxidation states of 99mTc in radiopharmaceuticals and kits for 99mTc-labeling-: DTPA, GHA, DMSA, MIBI, MAG3, MDP, Phytates, ECD, EC, IDA compounds and Sulfur Colloid. Dextran colloid and labeled particles. Metal chelate and conjugates, 99mTc-tricarbonyl core, 99mTc-nitrido compounds, 99mTc- Hynic-TOC.

- **Altered bio distribution 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.

- **PET radiopharmaceuticals**
  Positron emitters and radiochemistry to produce, 18F-Sodium Fluoride, 18F-Fluorodeoxyglucose (FDG) , 18F- Fluorodopa , 18F-Fluorothymidine (FLT), 18F-MISO, 18F-FAZA, 18F-FET, 18F-FBA, 11C-Sodium Acetate, 13NH3 and H 15O. FDG synthesis and QC Details of automated steps involved during synthesis, QC done before supply for patient‟s use.

- **Molecular Imaging probes: Target specific radiopharmaceuticals**
  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, α-Melanocyte-Stimulating Hormone, Neurotensin, Substance P (SP), Cholecystokinin (CCK), Neuropeptide Y (NPY) reporter genes for imaging.

- **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. QA of PET radiopharmaceuticals by TLC scanner, HPLC and gas chromatography (GC). 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 beta- 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, Thalium-170, Rhenium-186, 188. Rhenium Chemistry, Rhenium-188, Production and Physical Characteristics, Issues with Column Generator Production, Uptake and Biokinetic Properties, Rhenium RPs.

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

  Yttrium-90: Production and physical characteristics, 90Sr/90Y generators, uptake and biokinetic properties, uses of 90Y Radiopharmaceuticals: microspheres, MAA, antibodies, dosimetry.
  Auger-electrons emitting Radioisotopes: 111Indium (111In): Production and physical characteristics, uptake and biokinetic properties, dosimetry. Application of therapeutic radiopharmaceuticals: Bone pain palliatiation, Radio synovectomy, Radioimmunotherapy.

- **Alpha emitting Radioisotopes for therapy**
  223Radium-: Alpharadin, (Generator prod. RP 227Ac - 223Ra), 212Bismuth, (212Bi is produced by chemistry generator from 224Ra), 213Bismuth (213Bi is produced by chemistry generator from 225Ac), 211Astatium: (cyclotron produced RP. 209Bi (α, 2n) 211At), 225Actinium: Cyclotron produced RP. 226Ra (p, 2n) 225Ac. Production and physical characteristics, uptake and biokinetic properties.

- **Layout planning of Radiopharmacy laboratory**

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

- **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.

- **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 and applications.

  - **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**
    Bio distribution of radiolabeled radiopharmaceuticals in animals & 2. Animal Imaging

- **Internal consent, documentation and record keeping.**

Outcomes:

- Understand and apply knowledge of various radionuclides and radiopharmaceuticals in clinical nm including the fundamentals of radiolabelling procedures, quality control, bio-distribution and altered biodistribution.
- Understand and apply knowledge of PET radiopharmaceuticals and Molecular Imaging probes
- Learn therapeutic applications of radionuclides, Alpha-, Beta-, and Auger emitters
- Understand and apply knowledge of Alpha-, Beta-, Gamma-, Positron emitting Radionuclide
- Generators.
- Understand fundamental concepts of biomedical application of nanotechnology, and design of radiopharmacy laboratory.
- Understand fundamental concepts of Animal models and Ethical guideline for biomedical research

HLTH19-606: Non-Imaging Nuclear Medicine Instruments & Quality Control (31 Lecture)

Coordinators: Dr.Sushma Awasare
sawasare@barc.gov.in
Dr. Biju Menon,
bmenon@barc.gov.in

Course Details:

- **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, operation. Pocket dosimeter, Dose calibrator, Zone monitors.

- **Scintillation detectors – (Organic and 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: photopeaks, 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 and 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 solublizing 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.

- **Collimators & Probe systems**
  Collimator, Types of Collimators, Characteristics and its design. 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. Intraoperative Gamma Probe its

relevance in nuclear medicine, Quality Control.

- **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.

- **Instrumentation aspects of Medical Cyclotron**
  Reactors and charged particle accelerators. Physics of linear accelerator, cyclotron, synchro-cyclotron, isochronous cyclotron. Medical cyclotron: threshold energy, nuclear cross section, q value, RF frequency, magnets, beam focusing and extraction, target design. Types and makes their advantages and limitations. Safety Concerns. Cyclotron produced radionuclides, Cyclotron based generators.

- **Tutorials**

Course Outcomes:

- Understand and apply nuclear medicine related concepts of detectors like gas filled, liquid scintillation, organic and inorganic scintillation detectors, & semiconductor detectors, gamma ray spectrometry.
- Understand concepts of Collimator type, Probe systems, Whole body counters.
- Understand and learn Instrumentation aspects of Medical Cyclotron

HLTH19-607: Radiation Protection and In-Vitro & Non-Imaging Nuclear Medicine Techniques (43 Lecture)

Coordinators: Dr.Sushma Awasare
sawasare@barc.gov.in
Dr. Biju Menon,
bmenon@barc.gov.in

Course Details:

- **Radiation Protection**
  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. 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.

- **Radiation dosimetry**
  Metabolic pathways of radioisotope deposition, beta particle dosimetry; Equilibrium Dose rate equation. Gamma dose calculation, Specific gamma ray constant (Γ) and average geometrical factor. MIRD method of internal dose calculation, Absorbed Fraction, and calculation of absorbed dose.

- **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, 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 (lodine-131, Lutetium-177, etc). AERB directives for safe disposal of radioactive waste. Concept of Exclusion, exemption and clearance of radionuclide in solid materials.

- **Radiation protection in NM - Regulatory Aspects**
  Guidance level for diagnostic administration, misadministration, and preventive measures, reporting of misadministration.

  Layout of Nuclear Medicine Laboratory, Design of radiation labs, types of labs, Security of Sources and radioactive cautions signs and labels. 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, Regulatory clearance-Approval of NM Lab, Physician & RSO, Regulatory consent, authorisation- for disposal of radioactive waste and safe transport of Radioactive materials. Radiation Safety Program, Radiation Safety Officer and duties of Radiation Safety Officer, Radiation Safety Committee, Responsibilities for Implementation of Basic Safety Standards Requirements, AERB Regulation

Related to Medical Cyclotron and PET.

- **Non-imaging applications of radionuclides**
  ^{51}Cr 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 radiorespirometry 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 T_3, T_4, TSH, free hormones, thyroid antibodies and thyroglobulin, other hormones and drugs.

- **Radiolabeling of Cells**
  Methods of labelling for blood pool studies and detection of gastrointestinal bleeding. ^{99m}Tc-RBC (i.e. In- vitro, In-vivo and modified In-vivo), ^{99m}Tc- RBC‟s (denatured) for splenic imaging, ^{99m}Tc- / ^{111}In- - Leucocytes (i.e. Methods of radiolabeling for inflammation / abscess localization), ^{51}Cr- red blood cells (i.e. Methods of radiolabeling for blood volume measurement & Splenic Sequestration studies), ^{111}In-platelets (i.e. Methods for radiolabeling).

- **Tutorials**

- **Radiation Protection**
  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. 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.

- **Radiation dosimetry**
  Metabolic pathways of radioisotope deposition, beta particle dosimetry; Equilibrium Dose rate equation. Gamma dose calculation, Specific gamma ray constant (Γ) and average geometrical factor. MIRD method of internal dose calculation, Absorbed Fraction, and calculation of absorbed dose.

- **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, 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 (lodine-131, Lutetium-177, etc). AERB directives for safe disposal of radioactive waste. Concept of Exclusion, exemption and clearance of radionuclide in solid materials.

- **Radiation protection in NM - Regulatory Aspects**

Guidance level for diagnostic administration, misadministration, and preventive measures, reporting of misadministration.

Layout of Nuclear Medicine Laboratory, Design of radiation labs, types of labs, Security of Sources and radioactive cautions signs and labels. 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, Regulatory clearance- Approval of NM Lab, Physician & RSO, Regulatory consent, authorisation- for disposal of radioactive waste and safe transport of Radioactive materials. Radiation Safety Program, Radiation Safety Officer and duties of Radiation Safety Officer, Radiation Safety Committee, Responsibilities for Implementation of Basic Safety Standards Requirements, AERB Regulation Related to Medical Cyclotron and PET.

- **Non-imaging applications of radionuclides**
  ^{51}Cr 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 radiorespirometry 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 T_3, T_4, TSH, free hormones, thyroid antibodies and thyroglobulin, other hormones and drugs.

- **Radiolabeling of Cells**
  Methods of labelling for blood pool studies and detection of gastrointestinal bleeding. ^{99m}Tc-RBC (i.e. In- vitro, In-vivo and modified In-vivo), ^{99m}Tc- RBC‟s (denatured) for splenic imaging, ^{99m}Tc- / ^{111}In- - Leucocytes (i.e. Methods of radiolabeling for inflammation / abscess localization), ^{51}Cr- red blood cells (i.e. Methods of radiolabeling for blood volume measurement & Splenic Sequestration studies), ^{111}In-platelets (i.e. Methods for radiolabeling).

- **Tutorials**

Course Outcomes:

- 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 basic knowledge of radiation protection & dosimetry, waste management, radiation emergencies & preparedness in nuclear medicine setup
- Acquire and apply knowledge of tracer kinetic studies, radiolabelling of cells and its non-imaging applications.
- Understand and learn AERB Safety Directive, Safety code for NM facility, Duties of RSO, Regulatory -clearance, -consent, -authorisation for disposal and safe transport of radioactive materials

HLTH19-608: Nuclear Medicine Imaging Instruments & Quality Control (33 Lecture)

Coordinators: Dr.Sushma Awasare
sawasare@barc.gov.in
Dr. Biju Menon,
bmenon@barc.gov.in

Course Details:

- **Collimator Systems for imaging devices**
  Counting Geometry & Need for Collimator, Types of Collimator- Parallel Hole, Slant Hole, Rotating Hole, Focusing, Converging and Diverging Hole Collimators, Material design with regards to Cost, Geometric Efficiency and Resolution. Pinhole Collimator and its Adaptation in Gamma Camera. Fanbeam 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. Emerging designs and considerations of Multicrystal Gamma Camera.

- **Single Photon Emission Computerized 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, Performance characteristics, NECR, NEMA specifications, PET v/s SPECT, PET Protocols. Total body PET. Positron Emmision Mammography: (Basic principles, Instrumentation)

- **Application of Computers in Nuclear Medicine**
  Small animal imaging system designs – gamma camera, PET scanner and triple modality scanners.

- **Small animal imaging systems.**
  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. Hardware and software fusion – introduction, software and hardware fusion concept, merits and demerits of software hardware fusion.

- **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); Neural Networks, Telemedicine.

- **Introduction of ECG study**
  Introduction, 12 Lead ECG, normal ECG graph

Course Outcomes:

- Understand functioning of Nuclear Medicine imaging instruments, viz. rectilinear scanner, gamma camera, multicrystal gamma camera, SPECT, PET-CT and small animal imaging system.
- Learn and apply procedures for quality control of NM imaging instruments and quality assurance programs.
- Understand the role and application of Computer and Medical informatics in Nuclear Medicine.
- Learn basics of ECG

HLTH19-609: Recent Advances in Nuclear Medicine, Correlative Molecular Imaging and Therapy (43 Lecture)

Coordinators: Dr.Sushma Awasare
sawasare@barc.gov.in
Dr. Biju Menon,
bmenon@barc.gov.in

Course Details:

- **Introduction to Molecular Imaging**
  Cellular signalling mechanisms and molecular processes in cells, the biochemical probe for disease detection, chemical strategies to develop smart (sensitive & specific) imaging agents, translation from Insitu to Invivo systems, Sensors, probes and targeted delivery mechanisms, transfection, oligonucleotide probes reporter gene, and, photodynamic therapy, photosensitizers, stem cell tracking, apoptosis, radiolabeled monoclonal antibodies, production, isotopes used, mechanism of localization, factors effecting localization, implications in imaging & therapy.

- **Medical Imaging Technologies and Hybrid Imaging**
  Molecular mechanisms underlying diseases such as cancer, diabetes, heart disease and AIDS. Objectives of Correlative imaging and Image fusion, Implementation methods: -Instrumentation, -Software techniques, Display & Visualisation Schemes, Radionuclide Sources versus CT based methods, -Advantages and Drawback.

- **Radio guided Minimally Invasive Surgery using SPECT/CT**

- **Radiotherapy Planning using PET/CT**

- **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. Geometric accuracy(mm), high contrast spatial resolution(mm), slice thickness accuracy, slice position accuracy(mm), image intensity Uniformity(%), percent signal ghosting (%), low contrast object detectibility (contrast level), signal to noise ratio, central frequency (Hz).

- **Radiological Instrumentation - CT scanner**
  Discovery - Production - Properties of X-rays, basic requirements for diagnostic tubes, Classification of tubes, 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, , 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. Quality Control of CT- Tube Warm Up; Air Calibration; Radiation Safety Performance Test: Slice Thickness, Accuracy of Operating Potential, Accuracy of Timer, Coefficient of Length, Coefficient of Volume, CTDI test, High & Low contrast resolution, Total Filtration, Radiation Leakage test; Gantry table alignment; Table indexing Accuracy.

- **Advanced Molecular Imaging /other imaging modalities**
  Processes Involved in MI: Optical properties of cell, tissues and molecules. Interference, diffraction, polarization, birefringence phenomena, Luminescence, fluorescence, flurophores, chromophores. Optical (Fluorescence imaging Bioluminescent imaging (BLI) Cerenkov luminescence (CLI)., Optical Imaging Technologies, Near-infrared fluorescence imaging, Diffuse optical tomography, Optical Coherence Tomography (OCT), Diffuse optical spectroscopy, Confocal microscopy, Photoacoustic Tomography (PAT), Bremmsstrahlung imaging, peptide receptor imaging, radioluminescence microscopy (RLM)

- **Radionuclide Therapy**
  Clinical and Patient Management Aspect of Radionuclide Therapy- I-131 Low dose Therapy, I-131 high dose Therapy, I-131 MIBG Therapy, Bone Pain Palliation Therapy, Receptor based Therapy, Radiation Synovectomy , Interstitial therapy, - Indication to give therapy, Radionuclide therapy planning, Patient scheduling, Patient preparation, Formulation of radiopharmaceuticals, Dose dispensing, pre and post administration patient counseling, Post administration radiation survey, Record keeping, Discharge criteria of patient.

- **Advances in cancer therapy**
  Transarterial radioembolisation (TARE), Indication to give therapy, Radionuclide therapy planning and patient specific MIRD, Patient scheduling, Patient preparation, Formulation of radiopharmaceuticals, Dose dispensing, pre and post administration patient counselling, Post administration radiation survey, Record keeping, Discharge criteria of patient, TARE versus Transarterial chemoembolization (TACE) for liver cancer, Boron neutron capture therapy, Proton beam therapy- principle, instrumentation, advantages over conventional radiotherapy.

- **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.

- **Instruments Used in External Beam Radiotherapy, Brachytherapy**
  Lectures Introduction, working principle and operations of following equipments- Cobalt-60 unit (Bhabhatron), LINAC, IGRT, Tomotherapy, IMRT, Gamma Knife., Treatment planning system, GTV/PTV/CTV.

- **Neural Networks and Artificial Intelligence**
  Characteristics of Neural Networks, Historical Development of Neural Networks Principles, Artificial Neural Networks: Terminology, Models of Neuron, Topology, Feedforward / Feedback Neural Networks. Neural network developments in computer-aided diagnosis, medical image segmentation and edge detection towards visual content analysis, and medical image registration for its pre-processing and post-processing, with the aims of increasing awareness of how neural networks can be applied to these areas. Introduction to the basic principles of Artificial Intelligence and Deep learning technology as applied to medical imaging.

- **Introduction to Molecular Imaging**
  Cellular signalling mechanisms and molecular processes in cells, the biochemical probe for disease detection, chemical strategies to develop smart (sensitive & specific) imaging agents, translation from Insitu to Invivo systems, Sensors, probes and targeted delivery mechanisms, transfection, oligonucleotide probes reporter gene, and, photodynamic therapy, photosensitizers, stem cell tracking, apoptosis, radiolabeled monoclonal antibodies, production, isotopes used, mechanism of localization, factors effecting localization, implications in imaging & therapy.

- **Medical Imaging Technologies and Hybrid Imaging**
  Molecular mechanisms underlying diseases such as cancer, diabetes, heart disease and AIDS. Objectives of Correlative imaging and Image fusion, Implementation methods: -Instrumentation, -Software techniques, Display & Visualisation Schemes, Radionuclide Sources versus CT based methods, -Advantages and Drawback.

- **Radio guided Minimally Invasive Surgery using SPECT/CT**

- **Radiotherapy Planning using PET/CT**

- **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. Geometric accuracy(mm), high contrast spatial resolution(mm), slice thickness accuracy, slice position accuracy(mm), image intensity Uniformity(%), percent signal ghosting (%), low contrast object detectibility (contrast level), signal to noise ratio, central frequency (Hz).

- **Radiological Instrumentation - CT scanner**
  Discovery - Production - Properties of X-rays, basic requirements for diagnostic tubes, Classification of tubes, 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, , 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. Quality Control of CT- Tube Warm Up; Air Calibration; Radiation Safety Performance Test: Slice Thickness, Accuracy of Operating Potential, Accuracy of Timer, Coefficient of Length, Coefficient of Volume, CTDI test, High & Low contrast resolution, Total Filtration, Radiation Leakage test; Gantry table alignment; Table indexing Accuracy.

- **Advanced Molecular Imaging /other imaging modalities**
  Processes Involved in MI: Optical properties of cell, tissues and molecules. Interference, diffraction, polarization, birefringence phenomena, Luminescence, fluorescence, flurophores, chromophores. Optical (Fluorescence imaging Bioluminescent imaging (BLI) Cerenkov luminescence (CLI)., Optical Imaging Technologies, Near-infrared fluorescence imaging, Diffuse optical tomography, Optical Coherence Tomography (OCT), Diffuse optical spectroscopy, Confocal microscopy, Photoacoustic Tomography (PAT), Bremmsstrahlung imaging, peptide receptor imaging, radioluminescence microscopy (RLM)

- **Radionuclide Therapy**
  Clinical and Patient Management Aspect of Radionuclide Therapy- I-131 Low dose Therapy, I-131 high dose Therapy, I-131 MIBG Therapy, Bone Pain Palliation Therapy, Receptor based Therapy, Radiation Synovectomy , Interstitial therapy, - Indication to give therapy, Radionuclide therapy planning, Patient scheduling, Patient preparation, Formulation of radiopharmaceuticals, Dose dispensing, pre and post administration patient counseling, Post administration radiation survey, Record keeping, Discharge criteria of patient.

- **Advances in cancer therapy**
  Transarterial radioembolisation (TARE), Indication to give therapy, Radionuclide therapy planning and patient specific MIRD, Patient scheduling, Patient preparation, Formulation of radiopharmaceuticals, Dose dispensing, pre and post administration patient counselling, Post administration radiation survey, Record keeping, Discharge criteria of patient, TARE versus Transarterial chemoembolization (TACE) for liver cancer, Boron neutron capture therapy, Proton beam therapy- principle, instrumentation, advantages over conventional radiotherapy.

- **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.

- **Instruments Used in External Beam Radiotherapy, Brachytherapy**
  Lectures Introduction, working principle and operations of following equipments- Cobalt-60 unit (Bhabhatron), LINAC, IGRT, Tomotherapy, IMRT, Gamma Knife., Treatment planning system, GTV/PTV/CTV.

- **Neural Networks and Artificial Intelligence**
  Characteristics of Neural Networks, Historical Development of Neural Networks Principles, Artificial Neural Networks: Terminology, Models of Neuron, Topology, Feedforward / Feedback Neural Networks. Neural network developments in computer-aided diagnosis, medical image segmentation and edge detection towards visual content analysis, and medical image registration for its pre-processing and post-processing, with the aims of increasing awareness of how neural networks can be applied to these areas. Introduction to the basic principles of Artificial Intelligence and Deep learning technology as applied to medical imaging.

Course Outcomes:

- Principle and functioning of complimentary imaging devices such as USG, CT & MRI. Recent advances in SPECT, PET, developments in detector systems including hybrid systems such as PET- MRI.
- To learn and understand Radio guided Minimally Invasive Surgery using SPECT/CT and RT Planning using PET/CT
- Acquire knowledge of molecular processes in design and delivery using sensors, probes and targeted delivery for molecular imaging.

- Acquire knowledge of Advanced Molecular Imaging /other imaging modalities
- Acquire knowledge of Radionuclide therapy and advances in cancer therapy like External Beam Radiotherapy and Brachytherapy.
- Learn and apply use of contrast agents in imaging.
- To acquire fundamental knowledge of Neural Networks and Artificial Intelligence as applied to medical imaging

HLTH19-610: Clinical Nuclear Medicine Techniques Part I (43 Lecture)

Coordinators: Dr.Sushma Awasare
sawasare@barc.gov.in
Dr. Biju Menon,
bmenon@barc.gov.in

Course Details:

- **Thyroid studies**
  Thyroid imaging and uptakes (^{99m}Tc and ^{13}1I), Perchlorate discharge test, T_3/T_4 suppression test, TSH stimulation test. ^{131}I whole-body imaging. Post Therapy Scans. Scan sessions.

- **Lung imaging studies**
  Ventilation lung imaging studies using gases (^{133}Xe, ^{81m}Kr), Inhalation images using aerosols, aerosols generators, mucociliary clearance, COPD, Pulmonary permeability using DTPA, perfusion imaging using MAA, Microsphere, and pulmonary embolism. Scan sessions.

- **Liver-spleen imaging**
  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. Scan sessions.

- **Hepatobiliary imaging**
  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. Scan sessions.

- **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, Duodeno-gastric reflux, Meckel‟s diverticulum imaging, GI bleeding with 99mTc-RBC, 99mTc-S. Collide. Advantages and disadvantages of each method. Scan sessions.

- **Scrotal Imaging**

- **Dacryoscintigraphy**

- **Scintimammography**
  Early and Delayed Imaging. Special Positions and Restraining means. Scan session.

- **Hysterosalpingography**

- **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}Tc-MIBI wash out studies. Scan sessions

- **Bone marrow imaging**
  Imaging techniques for visualisation of Bone marrow infiltration. Scan session.

- **Thyroid studies**
  Thyroid imaging and uptakes (^{99m}Tc and ^{13}1I), Perchlorate discharge test, T_3/T_4 suppression test, TSH stimulation test. ^{131}I whole-body imaging. Post Therapy Scans. Scan sessions.

- **Lung imaging studies**
  Ventilation lung imaging studies using gases (^{133}Xe, ^{81m}Kr), Inhalation images using aerosols, aerosols generators, mucociliary clearance, COPD, Pulmonary permeability using DTPA, perfusion imaging using MAA, Microsphere, and pulmonary embolism. Scan sessions.

- **Liver-spleen imaging**
  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. Scan sessions.

- **Hepatobiliary imaging**
  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. Scan sessions.

- **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, Duodeno-gastric reflux, Meckel‟s diverticulum imaging, GI bleeding with 99mTc-RBC, 99mTc-S. Collide. Advantages and disadvantages of each method. Scan sessions.

- **Scrotal Imaging**

- **Dacryoscintigraphy**

- **Scintimammography**
  Early and Delayed Imaging. Special Positions and Restraining means. Scan session.

- **Hysterosalpingography**

- **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}Tc-MIBI wash out studies. Scan sessions

- **Bone marrow imaging**
  Imaging techniques for visualisation of Bone marrow infiltration. Scan session.

Course Outcomes:

- Principle and functioning of complimentary imaging devices such as USG, CT & MRI. Recent advances in SPECT, PET, developments in detector systems including hybrid systems such as PET- MRI.
- Understand the role of nuclear medicine imaging in various disease processes.
- 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 imaging Thyroid, Parathyroid, Salivary, Lungs, Liver, Spleen,
- G.I. system, Breast, Scrotal, Bone marrow imaging and duct patency studies.
- 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.

HLTH19-611: Clinical Nuclear Medicine Techniques Part II (44 Lecture)

Coordinators: Dr.Sushma Awasare
sawasare@barc.gov.in
Dr. Biju Menon,
bmenon@barc.gov.in

Course Details:

- **Cardiac studies**
  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}Tl, ^{18}FDG and $^{13}NH_3$ for cardiac studies. Scan sessions.

- **Bone imaging**
  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, ^{18}F-Fluoride Bone Scans. Scan sessions.

- **Renal imaging studies**
  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 99mTc-GHA &99mTc-DMSA, Differential function by Geometric Mean. Scan sessions.

- **Brain imaging**
  Cerebral blood flow dynamic studies, Blood Brain Barrier imaging, Perfusion Imaging, Brain SPECT, Interventional methods, Cisternography, CSF leak, PET brain imaging, ^{99m}Tc- DAT and TRODAT Brain Scintigraphy. Scan sessions.

- **Tumour Imagingaging**
  ^{18}F-FDG PET Scans for Oncologic Staging and Evaluation of Post therapy status. Imaging for Medullar Carcinoma of Thyroid, Neural Crest Tumours, Apoptotic Imaging. Post Therapy Scans. Organ specific (cold spot, hot spot), nonspecific (^{67}Ga- Citrate, ^{201} Tl, ^{131}I MIBI, ^{99m}Tc Tetrofosmine, ^{18}F-FDG), Tumor type specific (^{131} I for papillary and follicular carcinoma,^{131}I mIBG (adrenal cortex), ^{131}I-6-beta- iodomethylnorcholesterol (NP-59) for adrenocortical imaging, , ^{99m}Tc Mebrofenin for hepatocellualar ca, Antibody (^{111}In Oncoscint, ^{99m}Tc CEA,^{111}In Prostascint, ^{99m}Tc-Verluma, peptide (^{99m}Tc-HYNIC TOC, ^{111}In Octriotide,^{68}Ga DOTATATE). Scan sessions.

- **Lymphoscintigraphy & Sentinel Node Scintigraphy**

- **Infection and inflammation**
  Use of Labelled Leukocyte, ^{99m}Tc-Ciprofloxacin, ^{68}Gallium for detection of Infectious foci. Discussion of imaging preferences. Scan sessions.

- **Positron Emission Tomography & Computer Tomography Imaging**

Clinical application of PET imaging, Artifacts, HRCT of Thorax & bone Contrast Enhanced Computer Tomography of Brain, Head & Neck, Thorax, abdomen and Pelvis, Tri-phasic Computer Tomography, Computer Tomography Perfusion study, Dynamic PET imaging. Scan sessions.

Course Details:

- **Cardiac studies**
  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}Tl, ^{18}FDG and $^{13}NH_3$ for cardiac studies. Scan sessions.

- **Bone imaging**
  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, ^{18}F-Fluoride Bone Scans. Scan sessions.

- **Renal imaging studies**
  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 99mTc-GHA &99mTc-DMSA, Differential function by Geometric Mean. Scan sessions.

- **Brain imaging**
  Cerebral blood flow dynamic studies, Blood Brain Barrier imaging, Perfusion Imaging, Brain SPECT, Interventional methods, Cisternography, CSF leak, PET brain imaging, ^{99m}Tc- DAT and TRODAT Brain Scintigraphy. Scan sessions.

- **Tumour Imagingaging**
  ^{18}F-FDG PET Scans for Oncologic Staging and Evaluation of Post therapy status. Imaging for Medullar Carcinoma of Thyroid, Neural Crest Tumours, Apoptotic Imaging. Post Therapy Scans. Organ specific (cold spot, hot spot), nonspecific (^{67}Ga- Citrate, ^{201} Tl, ^{131}I MIBI, ^{99m}Tc Tetrofosmine, ^{18}F-FDG), Tumor type specific (^{131} I for papillary and follicular carcinoma,^{131}I mIBG (adrenal cortex), ^{131}I-6-beta- iodomethylnorcholesterol (NP-59) for adrenocortical imaging, , ^{99m}Tc Mebrofenin for hepatocellualar ca, Antibody (^{111}In Oncoscint, ^{99m}Tc CEA,^{111}In Prostascint, ^{99m}Tc-Verluma, peptide (^{99m}Tc-HYNIC TOC, ^{111}In Octriotide,^{68}Ga DOTATATE). Scan sessions.

- **Lymphoscintigraphy & Sentinel Node Scintigraphy**

- **Infection and inflammation**
  Use of Labelled Leukocyte, ^{99m}Tc-Ciprofloxacin, ^{68}Gallium for detection of Infectious foci. Discussion of imaging preferences. Scan sessions.

- **Positron Emission Tomography & Computer Tomography Imaging**
  Clinical application of PET imaging, Artifacts, HRCT of Thorax & bone Contrast Enhanced Computer Tomography of Brain, Head & Neck, Thorax, abdomen and Pelvis, Tri-phasic

Computer Tomography, Computer Tomography Perfusion study, Dynamic PET imaging. Scan sessions.

Course Outcomes:

- Understand the role of nuclear medicine imaging in various disease processes.
- 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 imaging brain, bone, kidney, heart, tumor.
- Learn specific techniques applied for tumour imaging, Lymphoscintigraphy & Sentinel Node Scintigraphy, Infection and inflammation
- Clinical application of PET and CT imaging.

PRACTICAL SYLLABUS

List of Physics Practicals for Semester II

1. To measure Half Value Layer of β and γ emitters and to measure the absorption coefficients of different materials with gamma rays and beta particles
2. To study back scatter.
3. To determine the half life of a radioactive material.
4. To study the change in activity of a sample consisting of two independently decaying radioisotopes (or a mixture of isotopes)
5. To determine the plateau of GM tube and find out the dead time/ resolving time of GM counter.
6. To determine the efficiency of GM counter and find out the activity of the given unknown radioactive source.
7. Gamma ray spectrometry of 137Cs with a single channel analyzer Curriculum for MSc(NMMIT) Page **20** of **20** 26th July 2020
8. To find out the spectrum of energies emitted by a radioisotope by using gamma ray spectrometer. (e.g. 131I)
9. To study the statistics of radioisotopic measurements and observe the effect of background on the counting statistics.
10. To determine the energy resolution of spectrometer
11. To study the energy linearity of given spectrometer
12. 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.
13. To identify unknown radionuclide on the basis of its principal energy by using scintillation counter.
14. To perform quality control of Dose Calibrator.
15. Radiopharmacy procedure: Elution of generators and calculation of labelling efficiency.
16. To prepare 99mTc labeled radiopharmaceuticals involving the use of a single and a double vials preparation.
17. Determination of 99Mo breakthrough in 99mTc
18. Q.C. of radiopharmaceuticals by paper chromatography & to determine the Rf of 99mTc and the given labeled compounds by using ascending chromatography.
19. Rapid determination of radiochemical purity of radiopharmaceuticals.
20. Q.C. of PET radiopharmaceuticals by TLC scanner and HPLC
21. To estimate pipetting error and Estimation of Unknown Volume by Dilution principle.
22. Biodistribution study of radiopharmaceuticals. (*Demonstration*)
23. Perform Radioimmunoassay & IRMA.

List of Physics & Clinical Practicals for Semester IV

1. To study iso- response curve of Flat Field Collimator.
2. To study the line spread function of a parallel hole collimator at various depths.
3. To perform Quality Control of Planar Gamma Camera and assess uniformity by Flood source method.
4. To study the counting errors originating from sample geometry and determine Critical Volume for counting in a well counter.
5. To perform Tomography with Jaszczak Phantom and evaluate the results
6. Quality Controls of SPECT/CT system (*Demonstration*)
7. Quality Controls of PET/CT system (Uniformity, Attenuation correction, Partial volume effect, Co-registration evaluation of SPECT/CT & PET/CT, SUV measurements) (*Demonstration*)
8. Perform all nuclear medicine imaging procedures and analysis of the data (*Demonstration*)