PROGRAM

MD NUCLEAR MEDICINE

(Revised with effect from 2014-2015 onwards)
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Program Outcomes

PO1: Knowledge of basic principles of radiation physics and its subsequent applications, necessary in the practice of the subject.
PO2: Knowledge of radiation protection principles, necessary for safe practice of the subject.
PO3: Expertise in safe handling of radionuclides and their disposal.
PO4: Knowledge of International Commission for Radiological Protection (ICRP) and National Regulatory guidelines pertaining to nuclear medicine practice.
PO5: Knowledge of diagnostic tests, interpretation of results and pitfalls.
PO6: Competence in good clinical practice of therapeutic nuclear medicine and dosimetry.

Program Specific Outcomes

PSO1: Skill in practical aspects related to Physics, Instrumentation and its quality Control.
PSO2: Skill in preparation of radiopharmaceuticals and their quality control.
PSO3: Skill in detection of contamination in various workplaces.
PSO4: Skill in characterization of unknown isotopes.
PSO5: Skill in management of accidental spillage.
PSO6: Skill in GFR Estimation.
PSO7: Skill in the clinical experiment of osophageal transit time.
PSO8: Skill in the clinical experiment of gastric emptying time.
PSO9: Skill in the clinical experiment of renal transplant evaluation
PSO10: Skill in the clinical experiment of determination of Ejection Fraction and RWMA (wall motion).

CORE SUBJECTS

1. Basic Mathematics.
   a) Logarithmic & exponential functions
   b) Differentiatation & integration
   c) Simple first & second order differential equations & their solutions.
   d) Compartmental analysis.

2. Basic medical statistics
   a) Mean, Mode, Median
   b) Standard deviation percent standard error - standard error of Mean (SEM)
   c) Binomial, Poisson & Gaussian distribution, Estimations & confidence limits.
   d) Null hypothesis & significance tests (students test etc)
   e) Analysis of variation & covariation, correlation coefficient by curve fitting method of least square fit.
   f) Computer methods of analyzing medical data.

3. Fundamentals of electricity & electronics
   a) Electrical conductivity, charge, voltage, current & resistance, Coulomb’s law, Ohm’s law, D.C. & A.C.
b) Components of electronic circuits, active & passive elements: their function & applications.
c) Basic electronic circuits: power supply, amplifiers, oscillators, pulse shapers.
d) Introduction to digital electronics: ADC, DAC, logic units, integrated, circuits,
e) microprocessors.

4. **Basic principles of Immunology**:
   b) Immunoglobulins: Structure of immunoglobulins – variations in structure of immunoglobulins – comparison of immunoglobulin classes.
   c) Synthesis of antibody:
      • Types of immune response:
      • Role of lymphocytes & details about the immune response & functions – Two populations of Lymphocytes: T & B – cells.
      • Cellular co-operation in the immune response synthesis of humoral antibody
      • Immunological tolerance
      • Theories of antibody synthesis.
   d) “In vitro “ Immune reactions
   e) Precipitation – Antigen binding techniques – Immunofluorescence
   g) Hypersensitivity: Types of hypersensitive reactions, Autoimmunity.

5. **Basic principles of chemical reactions**
   • Fundamental concepts, oxidation, reduction, acids, bases, hydrogen, Ion concentration, dissociation constants, pH value, Ionic equilibria, buffer solutions.
   • Fundamental concepts of organic chemistry, hydrocarbons, aliphatic hydroxyl compounds, non aliphatic hydroxy compounds, aldehydes, ketones, carboxylic acids, esters amines, amides hydrogen derivatives.
   • Chemical bonds – electrovalent bond, covalent bond & co-ordinate covalent bond. Chelate compounds.

6. **Elements of anatomy & physiology** of different body organs considered in scintigraphy & other nuclear medicine investigations.

7. **Nuclear Medicine Instruments**

Block diagram & understanding of specifications of the following instruments, power supply, voltage regulators, count rate meter, oscilloscope display, video display, chart recorder, printers.

8. **Instrument maintenance**

General care & maintenance of the electronic equipment in nuclear medicine laboratory.
MAIN SUBJECTS:

1. RADIATION BIOLOGY
   a) Brief overview of interactions of ionizing radiation with matter.
   
   b) Sources of Radiation
      - Environmental - Natural, Manmade
      - Medical
      - Occupational
   
   c) Measurement of Radiation and its Effects
      - Exposure
      - Absorbed dose
      - Dose equivalent
   
   d) Review of Cell Biology –
      1. Cell structure, Molecular components, Cell reproduction
         - DNA synthesis
         - Mitosis
         - Meiosis
      2. Cell replication cycle
      3. Chemical effects of radiation.
      4. Radiation effects on Macromolecules.
      5. Cell survival curves.
      6. LD 50 effects.
      8. Relative biological effectiveness (RBE)
      9. Free radicals
      10. Target theory
      11. Radiation Genetics
         A. Causes and effects of genetic mutations
            1. Spontaneous mutation
            2. Mutagenesis
            3. Carcinogenesis
            4. Gene mutations and cancer
         B. Effects of radiation on DNA
         C. Chromosome and chromatid aberrations
         D. Repair versus mutation
   
   e) Cellular Responses to Radiation
      A. Stage of cell replication cycle versus radiosensitivity

Factors Affecting Cellular Response to Radiation
   RBE and LD_{50/30}
   Physical factors
Chemical factors
Biological factors

f) Radiosensitivity and Cell Populations. Law of Bergonie and Tribondeau

g) Tissue and Systemic Responses to Radiation
   A. Acute versus late effects
   B. Healing of irradiated tissue
   C. Total-body irradiation
      1. Sources of information
      2. Hematopoietic syndrome
      3. Gastrointestinal syndrome
      4. Central nervous system syndrome
      5. Cardiac shock syndrome

   A. Radiosensitivity of embryo/fetus
   B. Phases of embryonic/fetal development
   C. Effects of radiation versus phase of development

h) Late Effects of Radiation Exposure
   A. Relating radiation exposure to specific effects
      1. Dose versus effect models
      2. Problems associated with researching radiation-induced effects/disease
         Non-specific life-shortening
         Genetic effects (spontaneous mutation versus radiation induced damage)
         Carcinogenesis
         Cataract instigation
         Other diseases

   i) Radiation doses
      A. Factors influencing absorbed dose from internal sources
         1. Concentration and organ mass
         2. Effective half-life
         3. Physical and chemical characteristics of radionuclide
         4. Absorbed fraction
         5. Cross-irradiation
      B. Critical and target organs
         1. Target organs
         2. Non-target critical organs
         3. Gonadal exposure
      C. Absorbed dose calculations
         1. Classical and MIRD methods
         2. Formulas
         3. Charts and tables

   j) Risk-to-Benefit Ratios
      A. Radiation hazard versus medical need
      B. Diagnostic exposures
1. Exposure from various sources (x-ray, computed tomography, etc.)
2. Radiation levels in nuclear medicine
C. Therapeutic exposures
   1. Exposure from various sources (radiation therapy, implants, etc.)
   2. Radiation levels in nuclear medicine

NUCLEAR PHYSICS

1. **Structure of atom**: Different models of atom, Physical & chemical properties. Avogadro’s Number, Periodic table, isotopes, isobars & isotones.
2. **Radioactivity**: Nuclear forces, nature & origin of radioactivity, types of radiations, nuclear transitions, units of radioactivity, physical properties of radioactivity, radioactive decay, decay schemes, trilinear radionuclide chart, physical half life, decay constant, average life, biological & effective half life, radionuclides in equilibrium, natural & artificial radioactivity.
3. **Production of radioisotopes**: Fission process, nuclear reactions, nuclear reactors, accelerators, medical cyclotrons, nature & properties of artificially produced radioisotopes.
4. **Interaction of radiation with matter**:
   - Interaction of alpha & beta particles with matter, scatter, ionization, bremsstrahlung, cerenkov, annihilation reactions.
   - Interaction of gamma radiation with matter: scatter, photoelectric effect, pair production
   - Penetration of radiation in matter, half value thickness, absorption coefficient, absorption cross section curves with respect to gamma energy & atomic number. Range of radiations in tissue, lead & NaI (T1)

Radiation detection & measurement

2. Scintillation detectors (solid): NaI (T1), CsI, BGO, LSO crystals, photomultiplier tube.
4. Semiconductor detectors: Principle, properties & use
5. Gamma ray spectrometer: Principle, operation & use.
7. Counting statistics: Standard deviation (SD) \, percent error measurement of SD of addition, subtraction, multiplication & division of two countrates.
Health Physics:
1. Units & definitions: Radiation, exposure, absorbed dose in air & in man, SI units.
3. Radiation protection: Evaluation of radiation hazards, protection measures, shielding personal & area monitoring, internal radiation hazards, control of contamination waste disposal, permissible levels, techniques of licensing.
5. Internal radiation dosimetry: Estimation of radiation dose delivered to various body organs & total body by internally administered radionuclides for diagnostic & therapeutic purposes by MIRD methods.

Scintigraphy (Instrumentation)
1. Rectilinear scanners: Instrument & principle of working, collimators & their evaluation, technique of scanning on a scanner, limitations & pitfalls concept of information density in imaging, various types of scanners.
2. Scintillation cameras: Description of instrument and principle of working collimators & their evaluation, technique of organ imaging on a scintillation camera, limitations & pitfalls, how to choose a scintillation camera.
3. Other imaging devices (emission type): Positron emission tomography system, Fresnel zone plate camera, semiconductor camera, multiwire proportional counter camera.
4. Tomography: Concept of tomography in imaging, emission tomographic cameras.

Other imaging modalities
1. Computerised Tomography
2. Ultrasonic imaging.

DYNAMIC STUDIES IN NUCLEAR MEDICINE
1. Instrumentation: Clinical analyzer, computers description & principle of working of the computer. Technique of performing dynamic studies with computer, Limitations & pitfalls.
2. Nuclear Cardiology: Radiopharmaceuticals, first pass & multigated equilibrium studies, determination of cardiac shunts, ejection fractions at rest & in stress, coronary blood flow
studies – wall motion studies, newer developments in nuclear cardiology techniques. Clinical evaluation of the nuclear cardiology techniques, its merits.


4. Dynamic studies using PET RP: Cerebral & cardiac reserve.

RADIOPHARMACEUTICALS:

1. General principles of tracer techniques.
2. Production of Radionuclides – SPECT & PET.
3. Reactor & its principle
4. Production of radionuclides in reactor
5. Cyclotron & its principle
6. Different generator systems
7. Production of radionuclides in cyclotron.
8. Linear accelerator
9. Betatron
10. Choice of radionuclides
11. Primary radionuclides – labeled compounds, Iodination, labeling with other radionuclides.
12. Therapeutic radionuclides
13. Purity of radiopharmaceuticals.
14. Chemical purity, Radiochemical purity, Radionuclide purity, Biological purity.
15. Stability of radiopharmaceuticals, parameters which affect stability
16. Quality control of radiopharmaceuticals
17. Radiochemical & chemical purity – methods used to determine.
18. Radionuclidic purity – methods used.
19. Sterility testing – methods used.
20. Pyrogen testing – methods used.
21. Various types of radionuclides generators
22. $^{99}$Mo – $^{99m}$Tc generator & preparation of different labeled compounds with Tc 99m.
23. $^{113}$Sn – $^{113m}$In generator & preparation of different labeled compounds.
24. $^{68}$Ge – $^{68}$Ga generator & preparation of different labeled compounds.
25. Other generators of interest in Nuclear Medicine.
27. Handling of radiopharmaceuticals.
28. Safety measures, equipments, shields, remote handling etc.
29. Dose preparation, packaging, storage, waste disposal
30. Economic aspects of radiopharmaceuticals
31. Legal aspects of radiopharmaceuticals.

CLINICAL SCINTIGRAPHY:

1. Brief review of anatomy of organ
2. Brief review of physiology
3. Radiopharmaceuticals used for imaging the organ & merits or demerits if any
4. Methods of localization of radiopharmaceuticals
5. Difference in SPECT & PET techniques, advantages, disadvantages
6. Use of SPECT CT & PET CT
7. PET MR imaging
8. Normal scan appearances in planar, SPECT & PET – normal physiological & anatomical variations
9. Artifacts in scan interpretations
10. Abnormal scans with respect to clinical diagnostics
11. Procedures of all planar, SPECT & PET scans
12. Indications & usefulness of scan with respect to clinical diagnosis
13. Limitations of information obtained by scans
14. Newer modalities of imaging like ultrasound, CT, NMR & comparison with nuclear medicine techniques.

THYROID FUNCTION STUDIES

1. Physiology of thyroid gland – Iodine metabolism in man
2. In vivo thyroid function tests: Thyroid uptake, PB 131 I, T3 suppression, TSH stimulation, perchlorate discharge test, Techniques of performing these tests, their limitations.
3. In vivo thyroid function tests: PB I, T3 – charcoal ratio, T3 – RBC uptake, competitive protein binding assays for T3, T4, free T4 & FTR, merits & demerits, factors affecting these tests.

THERAPEUTIC APPLICATIONS OF RADIONUCLIDES:

1. Treatment of hyperthyroidism with radioiodine,
2. Treatment of thyroid cancer,
3. Bone pain palliation
4. Therapy for polycythaemia vera
5. Radiosynovectomy
6. Monoclonal antibodies treatment
7. Other modes of internally administered isotopes for therapy.

Absorption studies:

1. Whole body counters: Instrument description, principle of working & technique of whole body counting, different types of whole body counters, their merits & demerits.
2. Basic principles of absorption studies, factors affecting absorption, clinical evaluation of these studies B-12 absorption studies, shielding test, double tracer technique, iron absorption, folic acid absorption, T3-T4 absorption – Dual marker technique.

Haematological uses of radioisotopes
Blood volume, RBC volume, plasma volume, RBC survival etc.

**In vitro techniques :**

1. **Tracer kinetics :** Principle of single compartment – multi compartment basic equations.
2. **Body fluids & electrolytes :** turnover of total body sodium, potassium etc.Total body water – Body composition of various electrolytes.
3. **Erythrokinetics – Iron kinetics, clinical usefulness, medullary & extra medullary erythropoiesis etc**
4. **Protein turnover studies – synthesis & catabolism – use of radioactive tracers in albumin turnover.**
5. **Radiorespirometry :** Glucose, palmitic acid & carbohydrate metabolism use of technique for bacterial contamination, drug sensitivity etc
6. **Neutron activation analysis – detection of tracer elements in biological samples.**
7. **Autoradiography**
8. **Biochemical applications of tracers**
   - Carbohydrate (Chemistry, metabolism)
   - Lipids (Chemistry, metabolism)
   - Proteins (Chemistry, metabolism)
   - Nucleic acids
   - Vitamins, Minerals & Enzymes

**RADIOIMMUNOASSAYS :**

1. **Principles of RIA.** General considerations in the preparation of iodine labeled tracers.
2. **Selection of suitable radioisotope, Radioactive labeling of proteins.**
3. **Mechanism of Iodination & structure of iodinated compounds.**
4. **Methods of iodination, Specific activity & substitution levels.**
5. **Iodination damage & quality control of iodinated tracers.**
6. **Stability of iodinated tracers.**
7. **Radioiodination & safety measures**
8. **Definition of antibodies, their function & mode of preparation.**
10. **Quality control measures in RIA’s.**

**Receptor assays :** Receptors, their physiological role mechanism of action & utility in clinical diagnosis.

**Enzyme immunoassay – Principles & applications in clinical diagnosis**

**Administrative aspects of Nuclear Medicine :**
1. Planning of radioisotope laboratory: Basic considerations, layout, equipment, classification of Nuclear Medicine laboratory, staff, clearance of premises, licensing for use of radionuclides in humans.
2. Cost benefit & efficacy of Nuclear Medicine investigations, role of Nuclear Medicine in diagnostic decision making, professional ethics.
3. Layout & commissioning of High dose RN Therapy wards
4. Layout & commissioning of PET CT

**PRACTICALS SYLLABUS:**

**RADIOPHARMACY PRACTICALS**

1. (a) Familiarisation with measurement of radioactivity using a dose calibrator.
   (b) K Factor for different radionuclides.
   (c) Determination of t 1/2 of short / intermediate / comparatively longer-lived RP
   (d) Theoretical concepts, Physics of instrumentation.

2. (a) Familiarisation with the handling of radioactivity – low & high level – safety practices, protection – wearing safety apparel.
   (b) Handling of radioactive sources – sealed / unsealed, remote handling equipment – tongs / forceps / shielded devices.
   (c) Actual handling of radioactive solutions in glass apparatus, both dummy & under real conditions of work up.
   (d) Concept of contamination, measurement, decontamination.
   (e) Theoretical aspects – health physics & radiation protection principles.

3. (a) Familiarisation with pharmacy practices – sterility, apyrogenicity, aseptic transfers, intravenous injections, clean environment, safeguards.
   (b) Withdrawal of injectable solutions, dispensing – same with radioactive solutions, micro-filtration, dose formulation with radioactive solutions.
   (c) Theoretical concepts – Pharmacy practices employed in preparation of pharmaceuticals (to be read).

4. (a) Familiarisation with radiochemistry practices, separations techniques – Solvent extraction / column chromatographic method of separation of 99m TcO4 – from 99MoO.

5. (a) Solvent extraction system – design of the system. Purification of 99m TcO4, injectable formulation of 99mTc – Radiopharmaceuticals. (The candidate is expected to familiarize
himself with the process & to perform the exercise at least 4 to 6 times under supervision).

(b) Cross-Contamination, Avoidance.
(c) Theoretical aspects to be studied.

6. Concepts of Quality assurance & control
   (a) Radionuclidic / radiochemical/ biological etc
   (b) Principles as applied to 99 m Tc-radiopharmaceuticals – absence of 99Mo, biodistribution, chromatography.

   (a) Criteria of integrity, lyophilized & other forms.
   (b) Theroretical principles (to be read).

8. Paper chromatography of 99mTcO4 in physiological saline
   (a) Counting procedures. (in general)
   (b) Rf value
   (c) Theoretical principles (to be read)

9. Paper chromatography of a few of the following injectables
   (a) Preparations, e.g. 99m Tc-MDP/ 99m Tc-DTPA/99mTc-S.Colloid / 99m Tc-Phytate.
   (b) Concept of purity. Inadequacies of the system. Alternate / complementary methods.

10. Trouble – shooting
    (a) Paper chromatography of designated 99m Tc-radiopharmaceuticals formulated from ‘kits’ of doubtful integrity, e.g. 99m Tc-MDP
    (b) Comparison of results.
    (c) Theoretical principles
    (d) Radionuclidic impurities estimation-
        All other radionuclide impurities: Not more than 0.1 mCi of all other B Emitters for mCi of 99m Tc at time of administration <0.001 mCi of gross & impurity / mCi of 99mTc at time of administration.
        Pyrogen, sterility requirements.
        Chemical purity

PHYSICS PRATICALS:

1. Characteristics of different radiations,
2. Absorption & back scatter of radiation,
3. Plateau of G.M.Counter,
4. Half valve layer,
5. Half life
6. Resolution of half lives from a mixture of radionuclides,
7. Daughter-parent relationship in radioactive decay and radionuclides,
8. Efficiency of counting,
9. Counting statistics,
10. Gamma gray spectrometry,
11. Identification of an unknown radionuclide,
12. Isoresponse curve of different collimators.
13. Lines spread function,
14. Liquid scintillation counting counting.
15. Autoradiography.
17. Radiation exposure : effect of distance
18. Shielding
20. Decontamination
22. Orcy soale calibaration. (Calibaration of a photo scanner)
23. Phantom studies for scintigraphy,
24. Flood field for scintigraphy.
25. Organ imaging.
27. Profile scanning.
28. Analog studies with single or multiple probes,
29. Dilution principle,
30. In vitro sample measurement of various types,
31. Flow measurements
32. Renogram
33. Thyroid uptake
34. Radioimmunoassays of various types.

COURSES

Course - I Basic Science (Code MDNM1)
CO1: Knowledge of radiation physics and instrumentation.
CO2: Knowledge of mathematics, statistics and computer sciences.
CO3: Knowledge of the biological effects of radiation exposure with emphasis on the effects of low level exposure. Knowledge of the methods of reducing unnecessary radiation to patients, personnel and environment.
CO4: Knowledge of the ICRP recommendations and their amendments from time to time and other international recommendations, environmental regulations, handling of radioactive patients, transport of radioactive material and disposal of radioactive wastes.
CO5: The diagnosis, evaluation and treatment of radiation over exposure in any form.

RADIATION BIOLOGY
   Brief overview of interactions of ionizing radiation with matter.

Sources of Radiation
  • Environmental - Natural , Manmade
• Medical
• Occupational
  Measurement of Radiation and its Effects
  • Exposure
  • Absorbed dose
  • Dose equivalent
  • Radiation and its effect on cell cycle
  • Tissue specific maximum dose of radiation

  Review of Cell Biology –
  Cell structure, Molecular components, Cell reproduction
  • DNA synthesis
  • Mitosis
  • Meiosis
  Cell replication cycle
  Chemical effects of radiation.
  Radiation effects on Macromolecules.
  Cell survival curves.
  LD 50 effects.
  Concepts of Clinical radiation pathology.
  Relative biological effectiveness (RBE)
  Free radicals
  Target theory
  Concept of Brachytherapy
  Radiation Genetics
  A. Causes and effects of genetic mutations
     1. Spontaneous mutation
     2. Mutagenesis
     3. Carcinogenesis
     4. Gene mutations and cancer
  B. Effects of radiation on DNA
  C. Chromosome and chromatid aberrations
  D. Repair versus mutation

**Cellular Responses to Radiation**
A. Stage of cell replication cycle versus radiosensitivity

Factors Affecting Cellular Response to Radiation
  RBE and LD_{50/30}
  Physical factors
  Chemical factors
  Biological factors

  Radiosensitivity and Cell Populations. Law of Bergonie and Tribondeau
  Tissue and Systemic Responses to Radiation
A. Acute versus late effects
B. Healing of irradiated tissue
C. Total-body irradiation
   1. Sources of information
   2. Hematopoietic syndrome
   3. Gastrointestinal syndrome
   4. Central nervous system syndrome
   5. Cardiac shock syndrome

A. Radiosensitivity of embryo/fetus
B. Phases of embryonic/fetal development
C. Effects of radiation versus phase of development

Late Effects of Radiation Exposure
A. Relating radiation exposure to specific effects
   1. Dose versus effect models
   2. Problems associated with researching radiation-induced effects/disease
      Non-specific life-shortening
      Genetic effects (spontaneous mutation versus radiation induced damage)
      Carcinogenesis
      Cataract instigation
      Other diseases

Radiation doses
A. Factors influencing absorbed dose from internal sources
   1. Concentration and organ mass
   2. Effective half-life
   3. Physical and chemical characteristics of radionuclide
   4. Absorbed fraction
   5. Cross-irradiation
B. Critical and target organs
   1. Target organs
   2. Non-target critical organs
   3. Gonadal exposure
C. Absorbed dose calculations
   1. Classical and MIRD methods
   2. Formulas
   3. Charts and tables

Risk-to-Benefit Ratios
A. Radiation hazard versus medical need
B. Diagnostic exposures
   1. Exposure from various sources (x-ray, computed tomography, etc.)
   2. Radiation levels in nuclear medicine
C. Therapeutic exposures
   1. Exposure from various sources (radiation therapy, implants, etc.)
   2. Radiation levels in nuclear medicine
NUCLEAR PHYSICS

Structure of atom: Different models of atom, Physical & chemical properties. Avogadro’s Number, Periodic table, isotopes, isobars & isotones.
Radioactivity: Nuclear forces, nature & origin of radioactivity, types of radiations, nuclear transitions, units of radioactivity, physical properties of radioactivity, radioactive decay, decay schemes, trilinear radionuclide chart, physical half life, decay constant, average life, biological & effective half life, radionuclides in equilibrium, natural & artificial radioactivity.
Production of radioisotopes: Fission process, nuclear reactions, nuclear reactors, accelerators, medical cyclotrons, nature & properties of artificially produced radioisotopes.
Interaction of radiation with matter:
- Interaction of alpha & beta particles with matter, scatter, ionization, bremsstrahlung, cerenkov, annihilation reactions.
- Interaction of gamma radiation with matter: scatter, photoelectric effect, pair production
- Penetration of radiation in matter, half value thickness, absorption coefficient, absorption cross section curves with respect to gamma energy & atomic number. Range of radiations in tissue, lead & NaI (T1)

Radiation detection & measurement
Radiation detectors (gas): Ionization chamber, proportional counters, GM counter – principles, operation & use in nuclear medicine.
Scintillation detectors (solid): NaI (T1), CsI, BGO, LSO crystals, photomultiplier tube.
Scintillation detectors (Liquid): Liquid organic scintillators sample preparation, quenching & its correction.
Semiconductor detectors: Principle, properties & use
Gamma ray spectrometer: Principle, operation & use.
Counting statistics: Standard deviation (SD), percent error measurement of SD of addition, substraction, multiplication & division of two countrates.

Health Physics:
Units & definitions: Radiation, exposure, absorbed dose in air & in man, SI units.
Radiation protection: Evaluation of radiation hazards, protection measures, shielding personal & area monitoring, internal radiation hazards, control of contamination waste disposal, permissible levels, techniques of licensing.

Internal radiation dosimetry: Estimation of radiation dose delivered to various body organs & total body by internally administered radionuclides for diagnostic & therapeutic purposes by MIRD methods.

**Course - II Clinical Nuclear Medicine I (MDNM2)**
CO1: Knowledge of radiopharmaceuticals.
CO2: Skill in in vivo diagnostic imaging.
CO3: Competence in in vitro studies.

**RADIOPHARMACEUTICALS:**

1. **General principles of tracer techniques.**
2. Production of Radionuclides – SPECT & PET.
3. Reactor & its principle
4. Production of radionuclides in reactor
5. Cyclotron & its principle
6. Different generator systems
7. Production of radionuclides in cyclotron.
8. Linear accelerator
9. Betatron

10. **Choice of radionuclides**
11. Primary radionuclides – labeled compounds, Iodination, labeling with other radionuclides.
12. Therapeutic radionuclides
13. Purity of radiopharmaceuticals.
14. Chemical purity, Radiochemical purity, Radionuclide purity, Biological purity.
15. Stability of radiopharmaceuticals, parameters which affect stability
16. Quality control of radiopharmaceuticals
17. Radiochemical & chemical purity – methods used to determine.
18. Radionuclidic purity – methods used.
19. Sterility testing – methods used.
20. Pyrogen testing – methods used.
21. Various types of radionuclides generators
22. $^{99}$Mo - $^{99m}$Tc generator & preparation of different labeled compounds with Tc 99m.
23. $^{113}$Sn - $^{113m}$In generator & preparation of different labeled compounds.
24. $^{68}$Ge – $^{68}$Ga generator & preparation of different labeled compounds.
25. Other generators of interest in Nuclear Medicine.
26. **Mechanism of localization of radiopharmaceuticals – modern trends in radiopharmaceuticals.**
27. Handling of radiopharmaceuticals.
28. Safety measures, equipments, shields, remote handling etc.
29. Dose preparation, packaging, storage, waste disposal
30. Economic aspects of radiopharmaceuticals
31. Legal aspects of radiopharmaceuticals.

**Course - III Clinical Nuclear medicine II (MDNM3)**

CO1: Knowledge of the principles of internal dosimetry.
CO2: Awareness about the characteristics of radionuclides/radiopharmaceuticals for radionuclide therapy.
CO3: Competence in radiation protection in therapeutic set up.
CO4: Knowledge of the principles of OPD and in-door therapy administration.
CO5: Skill in therapy in thyroid disorders.
CO6: Competence in bone pain palliation.
CO7: Skill in radiosynevectomy, radiopeptide therapy, radioconjugate therapy, radioimmunotherapy and locoregional internal radiation therapy.
CO8: Familiarity with research agents in radionuclide therapy.

**CLINICAL SCINTIGRAPHY :**

15. Brief review of anatomy of organ
16. Brief review of physiology
17. Radiopharmaceuticals used for imaging the organ & merits or demerits if any
18. Methods of localization of radiopharmaceuticals
19. Difference in SPECT & PET techniques, advantages , disadvantages
20. Use of SPECT CT & PET CT

**21. PET MR imaging**

22. Normal scan appearances in planar, SPECT & PET – normal physiological & anatomical variations
23. Artifacts in scan interpretations
24. Abnormal scans with respect to clinical diagnostics
25. Procedures of all planar, SPECT & PET scans
26. Indications & usefulness of scan with respect to clinical diagnosis
27. Limitations of information obtained by scans
28. Newer modalities of imaging like ultrasound, CT, NMR & comparison with nuclear medicine techniques.

**THYROID FUNCTION STUDIES**

4. Physiology of thyroid gland – Iodine metabolism in man
5. In vivo thyroid function tests : Thyroid uptake, PB 131 T, T3 supression, TSH stimulation, perchlorate discharge test, Techniques of performing these tests, their limitations.

**THERAPEUTIC APPLICATIONS OF RADIONUCLIDES :**

8. Treatment of hyperthyroidism with radioiodine,
9. Treatment of thyroid cancer,
10. Bone pain palliation
11. Therapy for polycythaemia vera
12. Radiosynovectomy
13. Monoclonal antibodies treatment
14. Other modes of internally administered isotopes for therapy.

Absorption studies:

3. Whole body counters: Instrument description, principle of working & technique of whole body counting, different types of whole body counters, their merits & demerits.
4. Basic principles of absorption studies, factors affecting absorption, clinical evaluation of these studies B-12 absorption studies, shielding test, double tracer technique, iron absorption, folic acid absorption, T3-T4 absorption – Dual marker technique.

Haematological uses of radioisotopes

Blood volume, RBC volume, plasma volume, RBC survival etc.

In vitro techniques:

11. Erythrokinetics – Iron kinetics, clinical usefulness, medullary & extra medullary erythropoiesis etc
13. Radiorespirometry: Glucose, palmatic acid & carbohydrate metabolism use of technique for bacterial contamination, drug sensitivity etc
15. Autoradiography
16. Biochemical applications of tracers
   Carbohydrate (Chemistry, metabolism)
   Lipids (Chemistry, metabolism)
   Proteins (Chemistry, metabolism)
   Nucleic acids
   Vitamins, Minerals & Enzymes

Course - IV Recent Advances (MDNM4)
CO1: Familiarity with recent advances in instrumentation
CO2: Familiarity with recent advances in radiopharmaceuticals.
CO3: Familiarity with recent advances in diagnostic procedures.
CO4: Familiarity with recent advances in radionuclide therapy.
Recent research activities and publications about the subject at the international level.
Awareness about recent innovations and treatment methodologies adopted in our country and other countries

Course V Soft Skills (MDNM5)
Elective Course
CO1: The attitude to be a lifelong learner.
CO2: The competence to do a clinical research and write a thesis/dissertation under supervision.

CO3: The skill to communicate with patients, caregivers and colleagues, based on foundation of ethics, and etiquette.
CO4: Teaching skills.
CO5: The ability to be a leader/member of a healthcare team, develop an attitude of cooperation with colleagues, and interact with the patient and the clinician or other colleagues to provide the best possible diagnosis or opinion.

Amrita School of Medicine,
Amrita Institute of Medical Sciences,
Kochi, Kerala

Department of Nuclear Medicine & PET CT

LOGBOOK

MD IN NUCLEAR MEDICINE

Name of student :-----------------------------

Course duration: Month of -------- Year upto --------

21
Date of Enrolment: Month of -------- Year upto --------

Log book for the month of: -------- Year --------

Total number of worked up cases:

WORKED UP CASES

CASE 1:

Name: Age/Sex: MRD:

CLINICAL INDICATION:

History

Examination

Salient Positive Findings

Scintigraphic Procedure

Scintigraphic Features

Other correlative Imaging details:

FOLLOW UP:
CASE 2:

Name: 
Age/Sex: 
MRD: 

CLINICAL INDICATION:

History

Examination

Salient Positive Findings

Scintigraphic Procedure

Scintigraphic Features

Other correlative Imaging details:

FOLLOW UP:

Signature of Head
Department of Nuclear Medicine
Amrita Institute of Medical Sciences

REPORTING RECORD:

PLANAR INVESTIGATIONS:

<table>
<thead>
<tr>
<th>PROCEDURES</th>
<th>NUMBER OF CASES</th>
</tr>
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<tbody>
<tr>
<td>Technetium Thyroid Scintigraphy</td>
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</tr>
<tr>
<td>I-131 Wholebody Scintigraphy</td>
<td></td>
</tr>
<tr>
<td>Procedure</td>
<td></td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>Tc MIBI Parathyroid Scintigraphy</td>
<td></td>
</tr>
<tr>
<td>I-131 Thyroid Scintigraphy</td>
<td></td>
</tr>
<tr>
<td>I-131 MIBG Imaging</td>
<td></td>
</tr>
<tr>
<td>Liver colloid &amp; Hepatobiliary Scintigraphy</td>
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</tr>
<tr>
<td>Tc- Salivary Scintigraphy</td>
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<tr>
<td>Esophageal Transit Scintigraphy</td>
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</tr>
<tr>
<td>GE Reflux Scintigraphy (Milk scan)</td>
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</tr>
<tr>
<td>Tc RBC GI Bleed Scintigraphy</td>
<td></td>
</tr>
<tr>
<td>Meckels Technetium Scintigraphy</td>
<td></td>
</tr>
<tr>
<td>Tc RBC Blood pool Scintigraphy</td>
<td></td>
</tr>
<tr>
<td>Motility Scintigraphy</td>
<td></td>
</tr>
<tr>
<td>Whole body Skeletal Scintigraphy</td>
<td></td>
</tr>
<tr>
<td>Sentinel scintigraphy</td>
<td></td>
</tr>
<tr>
<td>Tc MIBI Whole body Onco Scintigraphy</td>
<td></td>
</tr>
<tr>
<td>Lung Perfusion &amp; Aerosol Ventilation Scintigraphy</td>
<td></td>
</tr>
<tr>
<td>MUGA / RNV Scintigraphy</td>
<td></td>
</tr>
<tr>
<td>Direct / Indirect Radionuclide MCU</td>
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<tr>
<td>Testicular Scintigraphy</td>
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### SPECT & PET CT

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<tr>
<th>Special Investigations</th>
<th>No. of Cases</th>
<th>Impression</th>
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<td>MIBI Myocardial Perfusion Scan</td>
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<tr>
<td>MIBI Parathyroid Scintigraphy</td>
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<tr>
<td>Bone SPECT</td>
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</tr>
<tr>
<td>Liver SPECT</td>
<td></td>
<td></td>
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<tr>
<td>Brain SPECT</td>
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### PET CT Reported

### Procedures Performed Under Supervision

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<thead>
<tr>
<th>Date</th>
<th>MRD</th>
<th>Procedure</th>
<th>Indication</th>
<th>Complications</th>
<th>Follow Up</th>
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</table>

### Lectures and Presentations

| SRL No | Type | Date | Topic                  | Presented/Attended |
|--------|------|------|------------------------|--------------------|-------------------|

24
### SPECIAL INVESTIGATIONS

<table>
<thead>
<tr>
<th>MODALITY</th>
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<tbody>
<tr>
<td>Sentinel Imaging</td>
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<tr>
<td>I-131 Whole Body Scintigraphy</td>
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<tr>
<td>Lymphoscintigraphy</td>
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<tr>
<td>Scintimammography</td>
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<tr>
<td>MUGA Scan</td>
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### SPECIAL THERAPY PROCEDURES

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<thead>
<tr>
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<tbody>
<tr>
<td>Low Dose I-131 Therapy</td>
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<tr>
<td>High Dose I-131 Ablation</td>
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<tr>
<td>High Dose I-131 Mets Therapy</td>
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</tr>
<tr>
<td>Others</td>
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</tbody>
</table>

DATE: __________________________  SIGNATURE OF HEAD OF DEPARTMENT

Department of Nuclear Medicine
Amrita Institute of Medical Sciences

ANNEXURE V

QUARTERLY EVALUATION SHEET – PRACTICAL WORK

Name: __________________________

Date: __________________________
<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Point to be considered</th>
<th>Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Punctuality</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Regularity of attendance</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Quality of ward work</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Presentation of clinical cases</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Bedside manners</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Rapport with patients</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Rapport with colleagues</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Undergraduate teaching (if applicable)</td>
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</tr>
<tr>
<td>9</td>
<td>Physics &amp; instrumentation</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Understanding the concept</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Demonstrating the procedure</td>
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</tr>
<tr>
<td>12</td>
<td>Analysis of result</td>
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<tr>
<td>13</td>
<td>Record Maintenance</td>
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Guidance for scoring:

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<tr>
<td>1</td>
<td>Below average</td>
</tr>
<tr>
<td>2</td>
<td>Average</td>
</tr>
<tr>
<td>3</td>
<td>Above average</td>
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<tr>
<td>4</td>
<td>Very good</td>
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</table>

Total score

ANNEXURE VI

6 MONTHLY EVALUATION SHEET – PRESENTATIONS/JOURNAL CLUB

FOR THE PERIOD

Date:

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Point to be considered</th>
<th>Scoring</th>
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<tbody>
<tr>
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<td>Clinical Presentations</td>
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<tr>
<td>2</td>
<td>Whether all relevant points elicited</td>
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<tr>
<td>Sl.No.</td>
<td>Faculty Name</td>
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<tr>
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</tr>
<tr>
<td>1</td>
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<tr>
<td>2</td>
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<tr>
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**Guidance for scoring:**

<table>
<thead>
<tr>
<th>0</th>
<th>Poor</th>
<th>1</th>
<th>Below average</th>
<th>2</th>
<th>Average</th>
<th>3</th>
<th>Above average</th>
<th>4</th>
<th>Very good</th>
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**Total score:**

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<thead>
<tr>
<th>Sl.No.</th>
<th><strong>Point to be considered</strong></th>
<th>Scoring</th>
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<tbody>
<tr>
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<td>Instrumentation Presentation</td>
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<tr>
<td>2</td>
<td>Physics &amp; instrumentation</td>
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</tr>
<tr>
<td>3</td>
<td>Understanding the concept</td>
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</tr>
<tr>
<td>4</td>
<td>Carrying out the procedure</td>
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</tr>
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<td>5</td>
<td>Analysis of result</td>
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<tr>
<td>6</td>
<td>Record Maintenance</td>
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**Guidance for scoring:**
0 Poor  1 Below average  2 Average  3 Above average  4 Very good

Total score: 

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Faculty Name</th>
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<tbody>
<tr>
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<tr>
<td>2</td>
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<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
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</tbody>
</table>

Model Question Papers

Answer all questions in the given order
Total marks : 100, each question carries equal marks.
Time : 3 hrs

Paper I
1. Quality control of PET.
2. How will you maintain an optimal functioning of SPECT camera?
3. PET crystals.
4. Radiation monitoring instruments in nuclear medicine and the mechanisms on which they work.
5. Interaction of radiation with matter and their significance in nuclear medicine.
6. Phantoms and their uses.
7. a) N E C R
   b) 2D vs 3D PET acquisition
8. Radiation measurement quantities.
9. Attenuation correction
10. Common artefacts in SPECT and PET.

Paper II
1. Hereditary effects of radiation
2. How will you manage an accidental emergency in nuclear medicine department.
3. Regulatory aspects in setting up of a nuclear medicine laboratory.
4. Dose limits prescribed by ICRP and AERB.
5. Non-flourinated PET radiopharmaceuticals.
6. PET-based generators.
7. H. pylori breath test.
9. What are the types of equilibrium in relation to parent-daughter decay relationship?
10. How safe is nuclear medicine applications in children?

Paper III
1. Role of nuclear medicine in breast carcinoma?
2. Role of FDG-PET/CT in oncology
3. SPECT/CT in epilepsy.
4. Principles of radionuclide therapy
5. Compare RIA, ELISA and CLIA.
7. Various physical and pharmacological stress agents in cardiac perfusion imaging.
8. Radiation synovectomy.
9. Significance of interventions in nuclear medicine. Enumerate them and describe one in detail.
10. Parathyroid localisation methods.

Paper IV
1. Role of nuclear medicine in opportunistic infections
2. Apoptosis imaging
3. Prostate imaging
4. Future clinical applications of PET
5. Latest developments of nuclear medicine imaging in neuroendocrine tumours management
6. Imaging of angiogenesis and hypoxia
8. Coincidence detection systems. Its present day relevance.
9. Redifferentiation therapy and rh TSH in the management of thyroid cancer.
10. Imaging of dementia.