M.D. (NUCLEAR MEDICINE)

[Syllabus Approved by Board of Studies, Medical & Health Sciences]

Programme Code	HLTH09A06
Programme Details	MD NUCLEAR MEDICINE
Programme Learning Outcomes (PLOs / PSOs)	ANNEXED IN THE BELOW FORMAT
Eligibility Criteria	**AS PER NMC NORMS**
Duration of the Course	3 YEARS
Programme Structure (Credit-Based)	NA
Detailed Course Syllabus	ANNEXED IN THE BELOW FORMAT
Teaching–Learning Methodologies	3 YEARS RESIDENCY PROGRAM
Examination & Evaluation System	ANNUAL APPRAISALS FOLLOWED BY FINAL YEAR EXAMINATION AS PER NMC NORMS
Internship / Project / Dissertation Guidelines	1 YEAR MANDATORY BOND
Program In Charge	HEAD, DEPT OF NUCLEAR MEDICINE
Annexure (Books / Journals etc)	ANNEXED IN THE BELOW FORMAT

M.D. (NUCLEAR MEDICINE)

Programme Code: HLTH09A06

Programme Outcome:

- To develop Human Resource (Clinical Nuclear Medicine (NM) Physicians at the postgraduate level with MD qualification), possessing specialized knowledge in Theoretical, Experimental NM techniques and Clinical Nuclear Medicine, required for routine clinical practice encompassing Oncology, Cardiology, Nephrology, Endocrine disorders, Neurology and Skeletal Systems.

- Teaching and Training of basic and applied principles of Nuclear Medicine to study body structure and functions and use this information to diagnose and treat medical conditions, through uses of Radioactive materials called radiotracers or radiopharmaceuticals (both diagnostic & therapeutic) and Nuclear Medicine Instruments (such as PET-CT, Gamma camera and SPECT systems, Dose calibrator, radiation monitoring instruments).

- To train and introduce interdisciplinary subjects/concepts/ideas (Radiology, Cardiology, Oncology and other systems) for interdisciplinary application of Nuclear Medicine in management of specific system disorders

- To introduce the advanced concepts and emerging techniques with its applications in area of Nuclear Medicine (newer Radiopharmaceuticals, imaging techniques, newer clinical methodologies).

- Attain MD degree in Nuclear Medicine.

- Complete requisite training. Appraisal exams are held regularly to assess that the candidate attained knowledge in keeping with the objectives by year according to the syllabus of the course.

PROGRAMME CIRRICULUM

- **The syllabus is divided into the following four parts:**

1. Basic Science aspects of Radiation Physics and its application to diagnostic/ therapeutic Nuclear Medicine
2. Diagnostic Nuclear Medicine and its applications
3. Therapeutic Nuclear Medicine and its applications
4. Recent Advances in Nuclear Medicine

At the end of the course, the student should have acquired knowledge in the following:

Part I: Basic Science related to Nuclear Medicine

- **Radiation Physics and Instrumentation**

  - Structure of atom, Natural and artificial radioactivity.
  - Modes of Radioactive decay.
  - Interaction of radiation with matter.
  - Principles of radiation detection and detectors.
  - Basic principles of production of radionuclides by reactors and cyclotrons.
  - Nuclear Medicine Instrumentation including Gamma Cameras, Single Photon Computed Tomography (SPECT), Positron Emission Tomography (PET), Hybrid Imaging Systems like PET/CT and PET/MR
  - Counting Systems: Well counters, liquid scintillation counters, spectrometers, Radioactive Iodine Uptake (RAIU) probe and radiation monitoring devices.
  - Quality control of Nuclear Instruments, as in (f and g).
  - Collimation of radiation detectors and the characteristics of various collimators, their response to point, line and plane sources.
  - Electronic instruments, such as pulse amplifiers, pulse height analyzer, count rate meters and computer interfaces including gating systems.
  - Software and hardware fusion technology, Digital Imaging and Communications in Medicine (DICOM) technology and Picture Archiving and Communication System (PACS).

- **Mathematics, Statistics and Computer Sciences.**

  - Basic Mathematical concepts, counting statistics, probability distribution, Bayesian and McNamara statistics, parametric and non-parametric statistics.
  - Compartmental analysis and mathematical models of physiologic systems.
  - Basic aspects of computer structure, function and programming.
  - Computer applications with emphasis on digital image acquisition, analysis, processing and

enhancement, tomographic reconstruction, display and recordings of findings.
- Fundamental of filters, their applications and uses.

- **Radiation Biology**

  - The biological effects of radiation exposure with emphasis on the effects of low level exposure.
  - Methods of reducing unnecessary radiation exposure to patients, personnel and environment.
  - Dosimetry, MIRD, reference man, techniques for estimation
  - ICRP recommendations and their amendments from time to time and other international recommendations, environmental regulations. regarding limits of radiation exposure, handling of radioactive patients, transport of radioactivity material and disposal of radioactive wastes.
  - The diagnosis, evaluation and treatment of radiation over exposure in any form.
  - Biodosimetry

Part II: Diagnostic Nuclear Medicine

- **Radiopharmaceuticals**

  The chemical, physical and biological properties of radiopharmaceuticals used in Nuclear Medicine investigations; production, Quality Control and Regulations of hospital based-Nuclear Pharmacy.

  The emphasis will be on:

  - Physical and chemical characteristics of radionuclide used in diagnostic Nuclear Medicine
  - Criteria for selection of radionuclide for diagnostic purposes
  - Biological behavior of radiopharmaceuticals
  - Quality control
  - Mechanism of localization
  - Positron Emitting radionuclides, target reactions and their radiopharmaceuticals chemistry, various synthetic modules.
  - Specific topics on Radiopharmaceuticals: Bone seeking, hepatobiliary, brain and cerebrospinal fluid (CSF), renal, thyroid, parathyroid, infection imaging, Tumor Seeking, cardiac imaging etc.
  - Good Manufacturing Practice (GMP) and Laws pertaining to in-house manufacturing of Radiopharmaceuticals.
  - Radiopharmaceuticals for Research.
  - Principles of Production of Radioisotopes in reactors and accelerators.
  - Oral and IV contrast for CT & MRI

- **In vivo Diagnostic Imaging**

  - General clinical Indications for organ imaging; normal and altered anatomy, physiology, biochemistry and metabolism of various organs. Must learn the technical aspects of performing the procedure including proper patient preparation and patient management before, during and after the procedure.
  - In vivo imaging and/or functional studies including brain Single Photon Emission Computed

Tomography (SPECT), tracing of cerebrospinal fluid pathways, thyroid imaging, salivary glands, lungs, heart, gastrointestinal, hepatobiliary system, spleen, kidney, adrenal, bone and joints, bone marrow evaluation etc.

- The use of physiologic gating techniques for functional studies and patient monitoring during intervention, both physical exercise and using pharmacological stress agents
- Cellular kinetics, absorption and excretion analysis, nuclear hematology and metabolic balance studies using radiotracers.
- Principles of CT, MR and US imaging. Comparative analysis of Nuclear Medicine procedures with X-ray, Ultrasound, Echo, MRI, CT and angiography etc.
- Nuclear Cardiology: Stress and redistribution studies using Thallium201 and other technetium-based myocardial perfusion agents; myocardial viability, Gated SPECT studies, etc.
- Essential Knowledge of CT & MRI, so as to report findings of immediate consequence and those pertaining to hybrid imaging so as to provide comprehensive information for which the study was undertaken as a single examination. This is to abide by the principle of ALARA, to achieve the least radiation burden.
- Positron Emission Tomography (PET), PET-CT and PET/MR: All indications for use of PET-CT and PET/MR imaging in oncology, cardiology, neurosciences and psychiatric disorders, rheumatologically diseases and infection.
- PET-CT guided biopsy: technique, patient preparation and precautions.
- Grading and staging systems for various common cancers including breast, lung, prostate cancer, neuroendocrine tumors and lymphomas

- **In vitro Studies**

  - Radioactive Iodine Uptake measurements- Principles, quality control and data analysis for various metabolic conditions of Thyroid Gland.
  - Glomerular Filtration Rate (GFR) estimation

PART-III: Therapeutic Nuclear Medicine

- Principles of Internal Dosimetry: Calculation of the radiation dose from internally administered radionuclide
- Characteristics of Radionuclides/Radiopharmaceuticals for radionuclide therapy
- Radiation protection in therapeutic set up: Design of Isolation ward as per the norms of Atomic Energy Regulatory Board (AERB)
- Principles of OPD and in-door therapy administration
- Therapy in thyroid disorders; benign thyroid diseases, a etiology of hyperthyroidism, various modalities of treatment and follow up strategy, long-term outcome and various national and international regulations pertaining to therapeutic administration of radionuclides.
- Therapy in thyroid disorders; aetiopathology, classification and diagnosis of thyroid nodules and malignancies- various modalities of treatment and follow-up strategies, long-term outcome and various national and international regulations pertaining to therapeutic administration of radionuclides.
- Basic principles and common treatment protocols in oncology, especially w.r.t lymphomas, breast, prostate and lung cancers and neuroendocrine tumors

- Bone pain palliation using various radionuclides such as P32, Sr89, Sm153, Lu177 etc.
- Radiosynevectomy
- Radio peptide therapy and Radio conjugate therapy
- Radioimmunotherapy
- Loco regional internal radiation therapy
- Research agents in radionuclide therapy

Part IV: Recent Advances in Nuclear Medicine

Covering all aspects of the following areas:

- Instrumentation
- Radiopharmaceuticals
- Diagnostic procedures
- Therapeutic procedures

TEACHING AND LEARNING METHODS

Teaching methodology should consist of:
Didactic lectures in Physics related to Nuclear Medicine, radio pharmacy, radioisotopes techniques, instrumentation, data processing and quality control.

- Participation in the daily routine work of the department including ward rounds of patients admitted for radionuclide therapy.
- The postgraduate students shall be required to participate in the teaching and training programme of undergraduate students and interns.
- Presentation of cases in the reporting sessions of the department.
- **Log book:** Log book will be maintained meticulously to record all training done and Log books shall be checked and assessed periodically by the faculty members imparting the training.
- A postgraduate student of a postgraduate degree course in broad specialities/super specialities would be required to present one poster presentation, to read one paper at a national/state conference and to present one research paper which should be published/accepted for publication/sent for publication during the period of his postgraduate studies so as to make him eligible to appear at the postgraduate degree examination.
- Active participation in the combined clinical meetings with other departments for case discussions.
- Regular participation in department journal clubs, Seminars and other periodical CME programmes.
- Participation in the Seminars and CME programme of allied departments.
- Department should encourage e-learning activities.
- Rotation:
    - Apprenticeship/Rotation in:

a)	Radio-diagnosis	03 months [CT 2 mo and MR 1 mo]
b)	Cardiac stress lab	2 weeks
c)	Hospital Emergency	2 weeks
d)	Endocrinology OPD	2 weeks
e)	Oncology / Radiotherapy OPD	4 weeks

During the training programme, patient safety is of paramount importance; therefore, skills are to be learnt initially on the models, later to be performed under supervision followed by performing independently; for this purpose, provision of skills laboratories in medical colleges is mandatory

The year-wise schedule of training would be as follows:

Training in 1st Year:

- **Scientific principles:**
  - Basic physics and mathematics,
  - Instrumentation,
  - Principles of computing
  - Basic radiation biology and radiation protection,
  - Basic radiopharmacy and radiochemistry,
  - Principles of tracer technology.

- **Clinical Nuclear Medicine:**

  - **Diagnostic:** Normal and abnormal appearances of images, mode of pharmaceutical uptake; normal variants and common artifacts in bone, heart, lung, kidney, brain, thyroid, tumour and infection images. Principles of CT & MRI. Understanding selected Protocols and interpretations of CT & MRI, when performed as a part of simultaneous, PET/CT & PET/MRI.
  - **Therapeutic:** Basic principles of radionuclide therapy; treatment of hyperthyroidism, thyroid cancer and metastatic bone pain.
  - **Principles of radiation protection:** ALARA (as low as reasonably achievable) ALARP (as low as reasonably practicable).

Training in 2nd Year

- **Requirements of Year 1 in greater depth:**
  - Tracer kinetics;
  - Computing and image processing;
  - Radiobiology including the biological effects of high and low level radiation;
  - Linear hypothesis and the threshold hypothesis of the biological response to low level radiation;
  - The effective dose equivalent and the calculation of radiation dose from radiopharmaceuticals.

- **Radio pharmacy:**
  - Properties of commonly used diagnostic and therapeutic radiopharmaceuticals;
  - Production of radionuclides by reactors, cyclotrons and radionuclide generators;
  - Quality assurance and quality control of radiopharmaceuticals.

- **Diagnostic Nuclear Medicine:**
  - Tomography & hybrid SPECT-CT

- Integrated Protocols Of PET/CT & PET/MRI
- Optimization of CT & MRI protocols for simultaneous PET/CT & PET/MRI

Training in 3rd Year

- **Requirements of training of 1stv Year in greater depth:**
  - Principles of radiology including ultrasound, computerized tomography and magnetic resonance imaging.
  - Co-registration of nuclear medicine images and those from other imaging techniques.
  - Diagnostic: special investigations in cardiology, lung disease, gastroenterology, hepato-biliary diseases, nephro-urology, neurology and psychiatry, endocrinology, haematology, oncology and infection.
  - Radionuclide based hybrid imaging in oncology, cardiology, neurology, psychiatry, infection & inflammation, paediatrics, gastroenterology, and orthopedics.

- **Therapeutic applications:**
  - Treatment of bone metastases, neural crest tumors, prostate malignancies, solid malignancies;
  - Use of radionuclide monoclonal antibodies and radionuclide labeled peptides for tumor therapy.

- **Further practice and experience of work accomplished in years 1 to 3:**
  - Legal and regulatory requirements,
  - Audit,
  - Departmental management,
  - Research techniques and evaluation,
  - Teaching and training

Practical Training

The post graduate students are obliged to play an active 'in-service' role in the practice of Nuclear Medicine to familiarize themselves with all the techniques required as a nuclear medicine practitioner, such as:

- Protocols of in vivo and therapeutic procedures;
- Data acquisition and processing with various equipments, quality control of instruments and labeled agents;
- Interventional procedures, including physiological, pharmacological, and mental stress for diagnostic application, and all therapeutic interventions;
- In vitro protocols and procedures, if appropriate.

Since post graduate students will take on the responsibilities of a nuclear physician, they must pass a qualifying test that covers both theoretical knowledge and practical abilities in the daily practice of nuclear medicine.

SUGGESTED SCHEDULE FOR POST-GRADUATE TRAINING

Subject	Duration (hrs)	Suggested content of teaching	Recommended practice and time period
Nuclear physics	40	Decay features, spectrum, Radioisotope production & detection	Reactor-cyclotron generator, Radioisotope identification (5-7 days)
Radiochemistry	40	Labelling, technical design & quality control, interaction, kinetics	Synthesis, labelling, quality control, animal test (3-4 wks)
Radiobiology	40	Dosimetry, bio-modelling, tracer technology, radiation protection	Dosage-effect, molecular biology, radiation injury (4 wks)
Instrumentation	100	Scintillating camera, SPECT/CT, PET/CT, PET/MR imaging procedure, US examinations	Daily operation and quality control, trouble shooting (4 wks)
Related fields	50	Medical imaging modalities, epidemiology, statistics	Short round (6 wks)
Clinical use	240-300	Cardiology, neurology, GI tract, respiratory, endocrine, bones, haematology, tumour and infection	Clinical practice, image interpretation etc. (12-18 months)

Subject	Duration (hrs)	Suggested content of teaching	Recommended practice and time period
In-vitro use	10	RAIU, RBC mass, survival, hypersplenism	RAIU practice (2 wks)
		GFR measurements	GFR estimation (4 weeks)
Therapy	60	RIT, 177Lu-PRRT, 177Lu-PSMA Therapy, palliation, Loco-regional Therapies	Ward duty (3-4 months)

Postings in CT scan and MRI rooms are recommended as an aid to PET Scan imaging.

ASSESSMENT

FORMATIVE ASSESSMENT, during the training programme.

Formative assessment should be continual and should assess medical knowledge, patient care, procedural & academic skills, interpersonal skills, professionalism, self-directed learning and ability to practice in the system.

General Principles

Internal Assessment should be frequent, cover all domains of learning and used to provide feedback to improve learning; it should also cover professionalism and communication skills. The Internal Assessment should be conducted in theory and practical/clinical examination.

Quarterly assessment during the MD training should be based on:

- Journal based / recent advances learning
- Patient based /Laboratory or Skill based learning
- Self-directed learning and teaching
- Departmental and interdepartmental learning activity
- External and Outreach Activities / CMEs

The student to be assessed periodically as per categories listed in postgraduate student appraisal form (Annexure I).

SUMMATIVE ASSESSMENT, i.e., namely assessment at the end of the training

The summative examination would be carried out as per the Rules given in POSTGRADUATE MEDICAL EDUCATION REGULATIONS, 2000.

Post Graduate Examination will be in three parts:

- **Thesis**

  Every post graduate student shall carry out work on an assigned research project under the guidance of a recognised Post Graduate Teacher, the result of which shall be written up and submitted in the form of a Thesis. Work for writing the Thesis is aimed at contributing to the development of a spirit of enquiry, besides exposing the post graduate student to the techniques of research, critical analysis, acquaintance with the latest advances in medical science and the manner of identifying and consulting available literature.

  Thesis shall be submitted at least six months before the Theory and Clinical / Practical examination. The thesis shall be examined by two external examiners; who may or may not be the examiners for Theory and Clinical examination. A post graduate student shall be allowed to appear for the Theory and Practical/Clinical examination only after the acceptance of the Thesis by the examiners.

- **Theory Examination:**

  The examinations shall be organised on the basis of ‘Grading’or ‘Marking system’ to evaluate and to

certify post graduate student's level of knowledge, skill and competence at the end of the training. Obtaining a minimum of 50% marks in 'Theory' as well as 'Practical' separately shall be mandatory for passing examination as a whole. The examination for M.D. shall be held at the end of 3rd academic year. An academic term shall mean six month's training period.

There will be 4 theory papers:

Paper I: Basic Sciences related to Nuclear Medicine

Paper II: Diagnostic Nuclear Medicine

Paper III: Therapeutic Nuclear Medicine

Paper IV: Recent advances in Nuclear Medicine

Each theory paper to include a combination of long and short answer questions, to be completed in 3 hours. No MCQs.

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- **Practical/Clinical and Oral Examination**

Practical examination shall consist of carrying out special investigative techniques for diagnosis and therapy. Oral examination shall be comprehensive enough to test the post graduate student's overall knowledge of the subject.

There shall be:

1. One long case and two short cases.
2. One practical consisting of basic science concepts
3. Spots
4. Scan readings
5. Oral/viva-voce examination

References

Books

- The Pathophysiological basis of nuclear medicine by Abdelhamid Elgazzar
- Physics and radiobiology of nuclear medicine by Gopal B Saha
- Fundamentals of nuclear pharmacy by Gopal B Saha
- Neuro PET, by Herholz
- Molecular anatomic Imaging, by Von Schulthess
- Principles and Practice of Nuclear Medicine ,by Paul, J. Early, D. Bruce Sodee
- Diagnostic Nuclear Medicine, by Sandler and Gottchalk
- Nuclear Medicine in Clinical Diagnosis and Treatment, by Ell and Gambhir
- Positron Emission Tomography, by Valk, Bailey, Townsend
- Practical FDG Imaging A teaching File, by Debelke, Martin, Patton, Sandler.
- Functional Cerebral SPECT and PE Imaging
- CT and MR Imaging of the whole body, Haaga, Lanzieri, Gilkeson
- Multidetector CT : Principle Techniques and Clinical Applications, by Fishman Jeffrey Normal Lymph node Topography
- CT atlas, by Richter Feyerabind
- Therapeutic nuclear medicine by Richard P Baum
- PET/MRI In Oncology: Current Clinical Applications, Editors: Andrei Iagaru, Thomas Hope and Patrick Veit-Haibach
- PET/MRI: Methodology and Clinical Applications, Editors: Ignasi Carrio and Pablo Ros
- PET/MR Imaging: Current and Emerging Applications by Lale Umutlu, Ken Herrmann

Journals

03-05 international Journals and 02 national (all indexed) journals

- Seminars in Nuclear Medicine
- Journal of Nuclear Medicine
- Journal of Nuclear Medicine technology
- European Journal of Nuclear Medicine
- Nuclear Medicine communications
- Clinical Nuclear Medicine
- Annals of Nuclear Medicine
- Quarterly Journal of Nuclear Medicine
- World Journal of Nuclear Medicine
- Indian Journal of Nuclear Medicine
- Indian Journal of Radiology and Imaging
- Thyroid
- Radiographics
- Radiology
- British Journal of Radiology
- Theranostics

Annexure I

Postgraduate Students Appraisal Form
Pre / Para /Clinical Disciplines

Name of the Department/Unit :

Name of the PG Student :

Period of Training : FROM……TO……

Sr. No.	PARTICULARS	Not Satisfactory	Satisfactory	More Than Satisfactory	Remarks
		1 2 3	4 5 6	7 8 9	
1.	Journal based / recent advances learning				
2.	Patient based /Laboratory or Skill based learning				
3.	Self directed learning and teaching				
4.	Departmental and interdepartmental learning activity				
5.	External and Outreach Activities / CMEs				
6.	Thesis / Research work				
7.	Log Book Maintenance				

Publications Yes/ No

Remarks*_____
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***REMARKS: Any significant positive or negative attributes of a postgraduate student to be mentioned. For score less than 4 in any category, remediation must be suggested. Individual feedback to postgraduate student is strongly recommended.**

SIGNATURE OF ASSESSEE SIGNATURE OF CONSULTANT SIGNATURE OF HOD