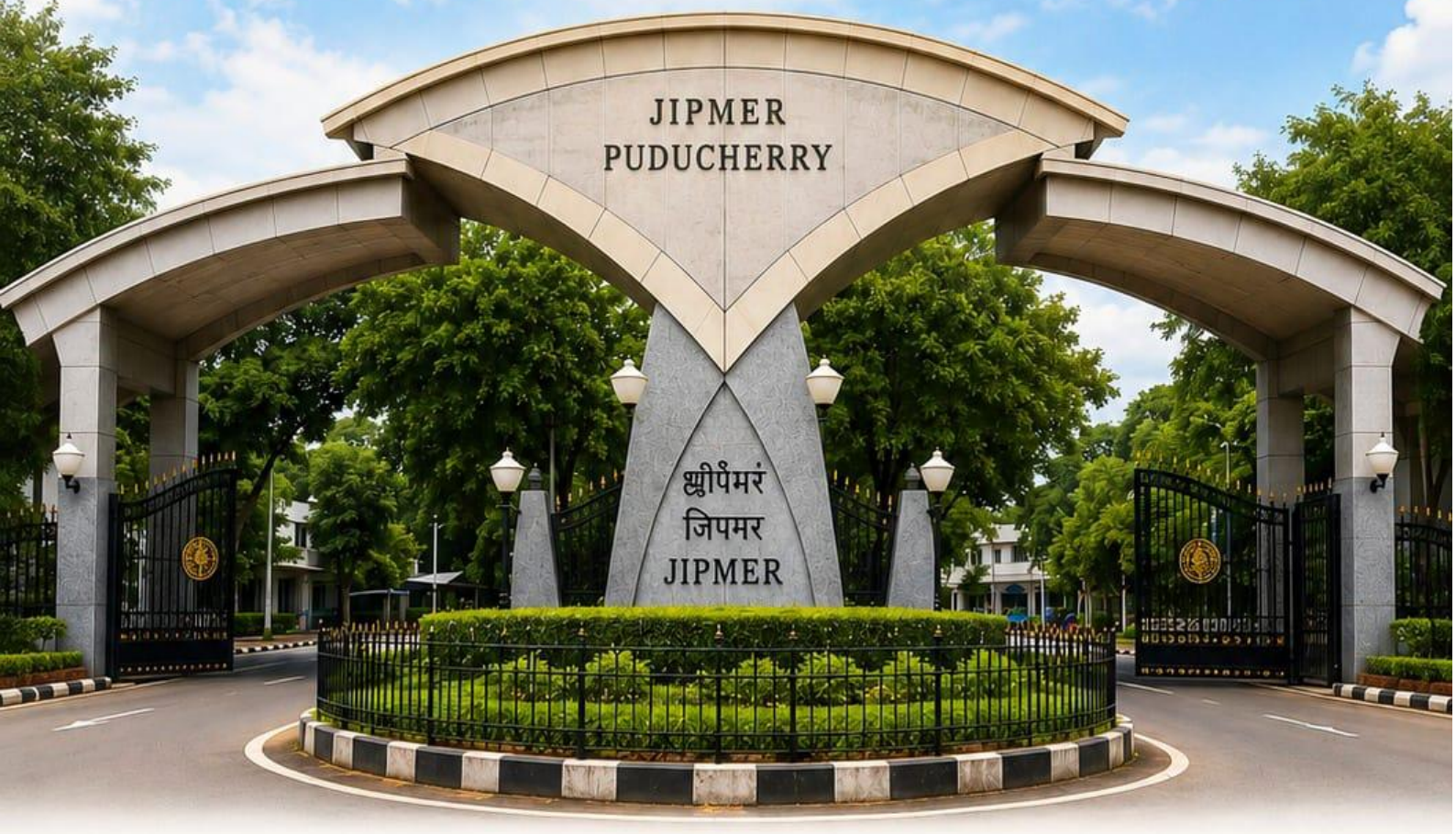
CURRICULUM

POSTGRADUATE

MD Nuclear Medicine

From July 2026 session



JAWAHARLAL INSTITUTE OF POSTGRADUATE MEDICAL EDUCATION AND RESEARCH (JIPMER),
PUDUCHERRY – 605 006.

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This curriculum was approved at the 19th meeting of the Standing Academic Committee held on 28th January 2026 and ratified at the 22nd meeting of the Governing Body and will be applicable for students joining MD Nuclear Medicine from the July 2026 session.

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GOAL OF THE COURSE

To produce honest and able nuclear physicians who can effectively perform and provide diagnosis based on imaging and non-imaging radionuclide procedures and provide appropriate therapy using radiopharmaceuticals using best possible evidence in medicine and with compassionate care to the patients, while striving towards bringing advancements in the field of nuclear medicine.

TERMINOLOGY

Key-capabilities

- They refer to the practices carried out by the specialists as part of their professional services.
- They represent the services required from them, by patients, students, other medical/healthcare staff or the society in general.
- Thus, they refer to the specific tasks that the postgraduate will be expected to do after he completes the course.
- For the purpose of training, the tasks are broken down into units that have distinct cognitive concepts, unless they are predominantly procedural, or attitude based.

Core ideas in practice of Key-capabilities

They refer to the ideas that underlie the practice of the specialists. They include ideas and concepts about structure and functioning of organs and organ systems in health and diseases, classification of diseases, radiation, detection equipment, need for and rational performance of diagnostic studies and therapy using radiopharmaceuticals, safe handling of radiation, etc.

COURSE CONTENT:

1. Key-capabilities in the practice of clinical oncology (outline below, details in Annexure 1 (Part A))

2. Core ideas in the practice of key-capabilities (outline below, details in Annexure 1 (Part B))

3. Peripheral postings, details in Annexure 1(Part C) and under 'Educational strategy'

(Please refer Annexure 1 for details)

KEY CAPABILITIES	
1	Radiation physics and instrumentation
2	Radiopharmacy
3	Radiation safety
4	Biostatistics
5	Concepts in management
6	Diagnostic Nuclear Medicine
7	Therapeutic Nuclear Medicine

LEARNING RESOURCES

(Suggested Books/ Online Resources)

Please refer to latest edition when available

S.No	Name of Book	Author	Edition	Publisher
Radiation Physics				
1	Physics in Nuclear Medicine	Simon R. Cherry, James A. Sorenson, Michael E. Phelps	4th, 2012	Elsevier/Saunders
2	Radiation Detection and Measurement	Glenn F. Knoll	4th, 2010	John Wiley & Sons
3	Physics and Radiobiology of Nuclear Medicine	Gopal B. Saha	4th, 2012	Springer
4	The Physics of Radiation Therapy	Faiz M Khan	6th, 2019	Lippincott Williams & Wilkins (LWW)
5	Fundamental Physics of Radiology	Meredith & Massey	3rd, 1984	Elsevier
6	Radiation Protection and Dosimetry	Stabin		
7	The Physics of Radiology and Imaging	Thayalan Kuppusamy	1st, 2014	Jaypee Brothers Medical Publishers
8	Basic Physics, Radiation Safety and Nuclear Medicine	G S Pant	2nd, 2018	Himalaya Publishing house
9	Principles and Practice of Nuclear Medicine	Paul J. Early, D.Bruce Sodee	2nd, 1994	Mosby

10	Principles and Practice of PET and PET/CT	Richard L. Wahl	2nd, 2008	Lippincott Williams & Wilkins (LWW)
11.	Nuclear Medicine and PET/CT - Technology and Techniques	David Gilmore, Waterstram-Rich, Kristen	8th, 2016	Mosby
12.	Molecular Imaging - Principles and Practice	Weissleder, Ross, Rehemtulla, SS Gambhir	2nd, 2021	Academic Press Inc
Radiobiology and cancer biology				
1	Radiobiology for the Radiologist	Eric J. Hall, Amato J. Giaccia	8th, 2018	Lippincott Williams & Wilkins (LWW)
2	The Pathophysiologic Basis of Nuclear Medicine	Abdelhamid H. Elgazzar	4th, 2022	Springer
Clinical Nuclear Medicine				
1.	Diagnostic Nuclear Medicine	Alexander Gottschalk	4th, 2002	Lippincott Williams & Wilkins (LWW)
2.	An atlas of clinical Nuclear Medicine	Fogelman I.	2014	Taylor & Francis exclusive (CBS)
3.	Diagnostic Imaging: Nuclear Medicine	Paige A Bennett MD	3rd, 2020	Elsevier - Health Sciences Division
4.	Nuclear Medicine - Cases	Joseph Rajendran, Vivek Manchanda	1st, 2011	McGraw Hill Education
5.	Essentials of Nuclear Medicine Imaging	Fred A. Mettler Jr., Milton J. Guiberteau	7th, 2018	Elsevier

6.	Quantitative Analysis in Nuclear Medicine Imaging	Habib Zaidi	2006	Springer-Verlag New York Inc.
7.	Nuclear Medicine: A core review	Chirayu Shah, MD Dalal, Ishani, Marques Bradshaw	2nd, 2021	Wolters Kluwer Health
8.	Pediatric Nuclear Medicine / PET	G.A. Taylor, S.T. Treves	3rd, 2007	Springer
9.	Nuclear Medicine: Principles and Practice	Robert E. Henkin, David Bova, Gary L. Dillehay	2nd, 2006	Mosby
	Nuclear Cardiology			
1	Clinical Nuclear Cardiology: State of the Art and Future Directions	Barry L. Zaret, George A. Beller	4th, 2010	Elsevier
2	Atlas of Nuclear Cardiology	Iskandrian	1 November 2011	Elsevier
3	Nuclear Cardiology Review - A self-assessment tool	Wael A. Jaber, Manuel D. Cerqueira	2nd, 2018	Lippincott Williams&WIlliams
4	Nuclear Cardiac Imaging: Principles and applications	Ami E. Iskandrian	5th, 2015	Oxford University Press USA
5	Cardiac SPECT Imaging	E. Gordon DePuey, Ernest V. Garcia, Daniel S. Berman	2nd, 2000	Lippincott Williams&WIlliams
6	Cardiac Imaging Cases	Charles White, Joseph Chen	1st, 2010	Oxford University Press USA

7	Cardiac Imaging: Illustrated Clinical Cases	Shahid Hussain, Jonathan Panting, Jun Kiat Teoh	1st, 2014	CRC press
8	Braunwald's Heart disease: A Textbook of Cardiovascular Medicine - Vol.1	Deepak Bhatt, FACC Mann, Douglas L., Harvard Medical S Braunwald, Eugene, Gordon F. Tomaselli, Peter Libby, Robert O. Bonow, Scott D. Solomon	12th, 2021	Elsevier
9	Braunwald's Heart disease: A Textbook of Cardiovascular Medicine - Vol.2		12th, 2021	Elsevier
10.	IAEA Atlas of Cardiac PET/CT	Marcelo F. Di Carli	26 April 2022	Springer
11.	Integrated Non-invasive Cardiovascular Imaging	Maurizio Dondi	June 2021	IAEA
12.	Goldberger's clinical Electrocardiography	Goldberger	14 June 2023	Elsevier
	Musculoskeletal Nuclear Medicine			
1	Orthopaedic Nuclear Medicine	Elgazzar	27 June 2011	Springer
2	Imaging of the foot and ankle	Berquist	24 September 2010	Lippincott Williams&WIlliams
3	Musculoskeletal Imaging	Pope	15 December 2014	Saunders
4	Diagnostic Imaging: Musculoskeletal and Non-traumatic disease	Manaster	4 May 2022	Elsevier
5	Diagnostic Imaging:	Blankenbaker	26 May 2021	Elsevier

	Musculoskeletal traumatic			
6	Diagnostic Imaging: Spine	Ross	13 December 2020	Elsevier
	Nuclear Oncology			
1.	Nuclear Oncology	Aktolun		
2.	Devita, Hellman, and Rsenberg's Cancer: Principles & Practice of Oncology	Vincent T. DeVita, Theodore S. Lawrence, Steven A. Rosenberg	12th, 2022	Wolters Kluwer Health
3.	Abeloff's Clinical Oncology	John E. Niederhuber, James O. Armitage, James H Doroshow, Michael B. Kastan, Joel E. Tepper	6th, 2019	Elsevier
	Nuclear Endocrinology			
1.	Williams Textbook of Endocrinology	Shlomo Melmed, Kenneth S. Polonsky, P. Reed Larsen, Henry M. Kronenberg	13th, 2016	Elsevier
2.	Werner & Ingbar's the thyroid: A fundamental and Clinical text	Lewis E. Braverman, David Cooper	10th, 2012	Lippincott Williams&WIlliams
	Nuclear Neurology			
1.	Neuro PET	Herholz	2004	Springer
2.	Functional Cerebral SPECT	Masanori Ichise,	4th, 2009	Lippincott

	and PET Imaging	Ronald L. Van Heertum, Ronald S. Tikofsky		Williams&WIlliams
	Nuclear Nephro-Urology			
1.	Functional Imaging in Nephro-Urology	Alain Prigent, Amy Piepsz	1st, 2019	Taylor & Francis
	Anatomical imaging			
1.	Weir & Abraham's imaging atlas of human anatomy	Spratt	25 June 2020	Elsevier
2.	Applied Radiological Anatomy	Butler	November 2012	Cambridge University Press
3.	Sectional Anatomy - MRI and CT	Anderson	14 May 2016, 5th edition available for pre-order	Elsevier
4.	CT and MRI of the whole body - Vol.1	Haaga	12 September 2016	Elsevier
5.	CT and MRI of the whole body - Vol.2	Haaga	12 September 2016	Elsevier
6.	Grainger & Allison's Diagnostic Radiology - Vol.1	Adam	June 2020	Elsevier
7.	Grainger & Allison's Diagnostic Radiology - Vol.2	Adam	June 2020	Elsevier
8.	MRI Made Easy (For Beginners)	Chavhan	27 May 2022	Jaypee
9.	Textbook of Radiology and	David Sutton	9 December	Churchill

	Medical Imaging - Vol.1		2002	livingstone
10.	Surface Anatomy	John S.P. Lumley	2 June 2008	Elsevier
11.	Molecular Anatomic Imaging: PET/CT, PET/MR and SPECT/CT	Vov, Schulthess	2015	Wolters Kluwer
12.	Sectional Anatomy - PET/CT and SPECT/CT	Edmund Kim, Mar, Inoue, Chung	2007	Springer
13.	Speciality Imaging - PET/CT	Blodgett	1 December 2008	Amirsys Inc.
	Biostatistics and Basic mathematics			
1.	Practical Mathematics in Nuclear Medicine Technology	Patricia Wells, MAE, CNMT	2011	Society of Nuclear Medicine
2.	Essentials of Biostatistics	Saha & Paul	1 January 2020	Academic publications
3.	Comprehensive textbook of Biostatistics & Research Methodology	Karthikeyan	1 January 2016	Bhalani

Suggested Journals

S. No	Journal Title Journal Home Page	Abbreviation Browse Journal in Medline	ISSN	Publisher
1	Journal of Nuclear Medicine	J Nucl Med.	1535-5667	SNMMI
2	European Journal of Nuclear Medicine and Molecular Imaging	Eur J Nucl Med Mol Imaging	1619-7089	Springer-Verlag Berlin
3	Clinical Nuclear Medicine	Clin Nucl Med	1536-0229	Philadelphia, Lippincott
4	Nuclear Medicine Communications	Nucl Med Commun	1473-5628	London : Lippincott Williams & Wilkins
5	Annals of Nuclear Medicine	Ann Nucl Med	1864-6433	Springer Japan
6	Indian Journal of Nuclear Medicine	Indian J Nucl Med	0974-0244	Society of Nuclear Medicine, India
7	Journal of Nuclear Cardiology	J Nucl Cardiol	1532-6551	New York : Springer
8	Seminars in Nuclear Medicine	Semin Nucl Med	1558-4623	Philadelphia, W.B. Saunders
9	PET Clinics	PET Clin	1879-9809	Philadelphia, Elsevier Saunders

EDUCATIONAL STRATEGY

1. Symposium presentations
2. Journal club
3. Case presentations
4. Interdepartmental meet presentations
5. Quiz
6. Lectures

Posting within Department

The postgraduate residents will be posted in different workplaces of the department on rotation at frequent intervals through the course. He/she will achieve the objectives of the posting in all these workplaces.

Duration of postings in different workplaces.

	SPECT	PET	Therapy	Peripheral posting (Radiodiagnosis)
First year	6	4	2	0
Second year	4	4	3	1
Third year	4	3	4	1
Total	**14**	**11**	**9**	**2**

Peripheral Posting

The postgraduate residents will be posted in different departments/divisions of the hospital/institute during the first two years of their course. The resident will be assessed for their knowledge, skills and performance in the department of peripheral posting. Attendance and feedback from these postings will be sent by respective departments to Nuclear Medicine.

Department	Basic Objectives	Duration
Radiodiagnosis	Learn the basic principles of various diagnostic modalities in radiodiagnosis.	4 weeks
Radiodiagnosis	Learn the indications and interpretation of normal scans and abnormal scans.	4 weeks

(May include more departments as needed/available not exceeding a total of 3 months)

Dissertation

- A research project should be undertaken and dissertation must be submitted as per Postgraduate Research Monitoring Committee (PGRMC) guidelines of JIPMER.
- Two hard copies of the dissertation, prepared from the research project, should be submitted to the Dean (Academics) JIPMER, at two and half years of the course to become eligible to appear for the final examination at the end of the course, as per the guidelines of JIPMER.
- Six monthly interim presentations of the dissertations will be done to monitor the progress of the research work and take corrective measures when faced with difficulties.
- **Please refer to Postgraduate Dissertation Regulations and Postgraduate Examination Regulations document for further details**

WORKPLACE OBSERVATION

Logbook

(Please refer Annexure 2 for sample forms)

1. A consolidated record of the number of cases, done independently and with assistance, of each procedure type is entered as per the format in **Annexure 2.** Each entry is made with date and is to be certified by faculty.
2. Detailed work-up of cases selected every month from posting in different workplaces (2 cases with different clinical diagnoses) will be maintained by the resident and entered in the logbook.
3. Record of academic activities (at department, institute or outside institute level) to be entered in the logbook are as following

   i. Presentation in departmental seminars
   ii. Presentations in journal clubs presented (with Title, Journal & Article reference)
   iii. Conferences attended – National/International
   iv. Papers presented at conferences with title, name of the conference, date of presentation (with abstract book)
   v. Papers published in journal (with article reference)
   vi. Peripheral postings : Feedback forms/score sheet filled by faculty members in other departments during the peripheral posting
4. Record of co-scholastic activities, if any

Workplace observation scheme

(Recorded at the end of every posting – submitted along with internal assessment marks)

(Please refer Annexure 3 for sample forms)

The day to day activities in practice and learning by the resident will be observed and recorded in the "workplace observation form", at pre-decided time instances.

Assessment of the logbook is to be done at the same time instances, and entry made in the 'workplace observation form' by the faculty.

Feedback, as part of formative assessment is given to residents, by faculty members, during these time instances

ASSESSMENT

Marks

Exam	Marks	Description
Theory exit examination	400 marks	This is the written exam at the end of the course. Four theory examination papers as given in the curriculum document of the course.
Practical exit exam	400 marks	This is the practical examination at the end of the course. The detailed scheme is given in the curriculum document of the course.
Internal Assessment	Internal assessment Theory: 50 marks	Two exams should be conducted - one at the end of first year and the other at the end of second year. Portions for the examination and pattern of the examination must be notified to the students at least one month in advance. The pattern of the internal assessment test will be similar to one paper of the theory exit examination. Two faculty members will evaluate the paper of each candidate in a blinded manner and the average of the 2 scores will be taken as the final score for the internal assessment. If a resident misses one of the tests due to medical reasons (medical certificate from a faculty member of the treating department and duly forwarded by the HoD to the Dean (Academic)), he/she can be permitted to appear in the test that is held for the next batch 6 months later. This can be permitted only once in the course period. If a resident does not attend an internal assessment test, or if he/she fails to attend the rescheduled test due to medical reasons, the score will be considered as 0 for the test. No retests or re-evaluation will be permitted under any circumstances. The internal assessment marks should be communicated to the students within two months of conducting the exams. Internal assessment test marks will be added to the final aggregate to the tune of 100 marks (theory and practical). There is no cut off of internal assessment test scores for determining eligibility to appear in the exit examination or to decide pass/fail solely based on the internal assessment test scores. However, when a student secures less than 50%

Exam	Marks	Description
		marks in the internal assessment or when any concern is formally raised by the student with the Dean office, a review board with at least 3 faculty members should be constituted to review the student's performance with the student, recommend appropriate remedial measures, document the remedial plan, and submit a signed copy of the document to the Dean's Office. Additional periodic assessments can be held as part of formative assessment. Scores of these tests will not be considered for internal assessment and will not be considered for replacing scores of any of the internal assessment tests. Information to be provided to the Dean Office, before the final examination. 1. Dates of internal assessment examinations conducted 2. Names of faculty members involved in assessment against each date 3. Marks obtained by students in theory, practical and workplace-based observation in each exam session 4. Internal assessment marks for each student for Theory, Practical and Workplace based assessment. An average of the two theory and practical tests will be used to calculate scores for 50 and 25 marks respectively. Cumulative workplace-based assessment scores will be determined for 25 marks. 5. Copy of review documentations for periods of low performance of a student, if any, with remedial measures suggested by the departmental committee.
Internal Assessment (Practical and Workplace-based assessment)	Internal assessment Practical: 25 marks Internal assessment	For practical examinations, all members of the faculty of the department, from Assistant Professor to the senior-most faculty, shall participate in internal assessment on a rotating basis. The assessment shall be planned such that multiple faculty members are engaged for each student and different faculty members are engaged for the two assessments, wherever feasible. The pattern prescribed in the curriculum document shall be followed for practical assessments and the score shall be adjusted for 25 marks. Workplace-based assessment marks are given based on practice of the profession and affective

Exam	Marks	Description
	Workplace-based assessment: 25 marks	domain attributes in the workplace and in the learning environment. Workplace observation proforma should be provided to students at the time of joining the department. The method of workplace observation should be explained to the students at the beginning of the course.
Dissertation	100 marks	Dissertation marks will be calculated by the average of the scores provided by 2 external examiners. Approval of the dissertation with more than 50% scores awarded by the external examiners will be one of the eligibility criteria for appearing for the exit examination of the discipline.
Total	1000 marks	**Criteria for PASS:** 1. (a) A candidate will need to pass the final Theory Exit Exam and Practical Exit Exam independently. (b) A minimum of 50% marks in 'Theory Exit exam' (a minimum of 40% in each of the four papers) and 50% in 'Practical Exit exam' separately shall be mandatory 2. A candidate should also score 50% or above in the final aggregate marks (500 out of 1000) to pass in the degree course. If a student secures a pass score in theory and practical examination but fails in the aggregate score, he/she can re-appear in the exit examination of the subsequent session. There is no provision to improve internal assessment or dissertation scores.
Please refer to Postgraduate Examination Regulations document for further details		

Theory Exit Exam (400 Marks)

A. Paper I: Basic sciences related to Nuclear Medicine

- Radiation Physics
- Physics and Instrumentation of nuclear medicine equipment
- Radiochemistry and Radiopharmacy
- Radiobiology
- Principles and application of Radiation dosimetry
- Radiation safety and protection
- Biostatistics
- Basic concepts in management

B. Paper II: Clinical Nuclear Medicine Part - 1

Clinical Nuclear Medicine imaging principles and applications in

- musculoskeletal system
- Endocrinology
- Gastrointestinal system
- Genitourinary system
- Cardiovascular system
- Pulmonary system

C. Paper III: Clinical Nuclear Medicine Part – 2

Clinical Nuclear Medicine imaging principles and applications in

- Neurology
- Oncology
- Infection and inflammation imaging

In-vitro procedures and

Radionuclide therapy

D. Paper IV: Recent advances in Diagnostic and Therapeutic Nuclear Medicine

- Recent advances in
  - instrumentation hardware and related software
  - radiopharmaceuticals
  - radiation safety practices and regulations
  - image processing and reporting
  - radionuclide therapy
  - recent guidelines
  - landmark clinical trials and research studies
- Artificial intelligence
- Principles and practice of other imaging modalities such as ultrasound, MRI, optical, fluorescence imaging, etc.

Practical Exit Exam (400 Marks)

A. Objective Structured Practical/Clinical Evaluation –Identification, Description and Utility

- Mathematical calculations in radiation physics, quality parameters of equipment, radiation dosimetry, radiation protection (20 marks)
- Demonstration of practical exercises (physics and instrumentation):
  - Quality control of equipment: SPECT/CT, PET/CT, dose calibrator, gamma well counter, thyroid uptake probe (20 marks)
- Demonstration of practical exercises (Radiopharmacy): (20 marks)

    - Elution of Mo-99m/Tc-99m generator and labelling of radiopharmaceuticals
    - Quality control of radiopharmaceuticals
- Demonstration of practical exercises (Imaging): (20 marks)
    - Acquisition of SPECT/CT and PET/CT scans
    - Reconstruction and processing of images
- Clinical examination and procedures: (20 marks)
    - Examination of thyroid, eye (orbitopathy)
    - Pain evaluation
    - Cardiac stress procedure

B. Exam Patient Cases/Scenarios- Two cases (One diagnostic and one therapy, 50 marks each)

- Patient History & Differential Diagnosis = 10 marks
- Patient Examination =10 marks
- Investigations & Clinical Tumour Staging =10 marks
- Discussion on the patient, disease and management= 20 marks

C. Scan reading session

D. General Viva (Practical aspects of planning and running a department)

Viva-Voce will include concepts and application of knowledge on the planning and operating a nuclear medicine facility.

MODEL THEORY QUESTION PAPERS

M.D. DEGREE EXAMINATIONS

NUCLEAR MEDICINE

Paper I - Basic sciences related to Nuclear Medicine

(Radiation Physics, Instrumentation, Radiochemistry and Radiopharmacy, Radiobiology, Radiation dosimetry, Radiation safety and protection, Biostatistics, and basic concepts in management)

Time: Three Hours **Maximum Marks: 100**

Answer all the following questions: (10 x 10 = 100 marks)

1. Enumerate various factors that influence the detection efficiency of an imaging device. If you plan to purchase a new PET scanner, what specifications would you choose in order to achieve highest detector efficiency for 511 keV photons? (8 + 2)
2. In a system that has both filtered back projection and ordered subset expectation maximisation options for image reconstruction of SPECT, which one will you prefer to use? Why?
3. A pregnant mother is exposed to __Gy of radiation in the third trimester. What consequences can be expected in the foetus? Why? What is the dose limits prescribed for pregnant radiation worker?
4. A patient with rheumatoid arthritis suffers from severe pain and swelling in her fingers. What option of radionuclide treatment is available for her? Propose a treatment regimen for her and describe the mechanism of action.
5. The counts from a radioactive sample measured 5 times were 10000, 13400, 12300, 13100, and 12900. Find the co-efficient of variance. Calculate the uncertainty in a single measured value of 10000 counts at 68% confidence interval. Suppose, if the error in the counting system is 2%, what would be the total error?
6. In a Tc-99m Methylene Diphosphonate bone scan done in a patient for skeletal metastatic evaluation, thyroid gland and gastric mucosa are visualised. What could be the possible reasons for this and how could it have been prevented? (4 + 6)
7. Enlist various radiopharmaceuticals available for myocardial perfusion imaging. Based on the characteristics of each of them, which would be the radiopharmaceutical of your choice and provide supportive argument. (3+7)
8. Write short notes on a. S factor in radiation dosimetry, b. MIRD phantom (5 + 5)
9. Why does hypoxia occur in a malignant tumour? What are its implications in the management of cancers and what solutions can be offered from nuclear medicine to achieve better cancer control? (3 + 2 + 5)
10. Enlist various imaging targets in Alzheimer's disease. Compare and contrast the possible utility of radiopharmaceuticals against each of these targets in the management of Alzheimer's disease. (3 + 7)

M.D. DEGREE EXAMINATIONS

NUCLEAR MEDICINE

Paper II - Clinical Nuclear Medicine Part - 1

(Clinical nuclear Medicine imaging principles and applications in musculoskeletal system, endocrinology, gastrointestinal, genitourinary, cardiovascular and pulmonary systems)

Time: Three Hours **Maximum Marks: 100**

Answer all the following questions: **(10 x 10 = 100 marks)**

1. Enumerate radiopharmaceuticals and imaging techniques in the evaluation of patients with suspected osteonecrosis. Describe how nuclear imaging can help in the management of such patients.
2. Enumerate radiopharmaceuticals that can be used to evaluate thyroid function. Enlist the indications and explain the procedure of perchlorate discharge test.
3. A patient presents with a history of thyrotoxicosis and her T3 and T4 are elevated. Thyroid scan shows severely reduced uptake in the thyroid. What could be the possible diagnoses? Provide supporting arguments
4. A 56 year old male with Type II Diabetes mellitus complains of post-prandial bloating sensation of abdomen. Physical examination and gastroduodenal endoscopy revealed no abnormality. What could be the differential diagnoses and how can nuclear imaging help in the management of this patient?
5. A 4 year old child with a history of melena since 2 days comes to the emergency department. The child is however stable and ultrasound of the abdomen is normal. What investigation would you do? Explain the procedure and interpretation.
6. A child was diagnosed to have hydronephrosis of the left kidney antenatally. Her post-natal ultrasound showed a transpelvic diameter of 2 cm and reduced parenchymal thickness of left kidney. Recommend a management plan for the child.
7. A 50 year old obese male with suspected coronary artery disease undergoes adenosine stress myocardial perfusion SPECT. The inferior and inferolateral segments show moderately reduced tracer uptake. Discuss various causes for the defect and explain how you will arrive at a diagnosis.
8. Describe the role of nuclear medicine in pre-operative cardiac evaluation of patients undergoing non-cardiac surgery.
9. What is myocardial viability? Enumerate various nuclear and non-nuclear methods of myocardial viability assessment. Describe how viability assessment impacts management of patients with coronary artery disease. (2 + 3 + 5)
10. In this era of multi detector CT, what is the current role of ventilation-perfusion scintigraphy in the setting of acute pulmonary embolism?

M.D. DEGREE EXAMINATIONS

NUCLEAR MEDICINE

Paper III - Clinical Nuclear Medicine Part - 2

(Clinical Nuclear Medicine imaging principles and applications in neurology, oncology, infection and inflammation imaging, In-vitro procedures and Radionuclide therapy)

Time: Three Hours **Maximum Marks: 100**

Answer all the following questions: **(10 x 10 = 100 marks)**

1. Describe the role of dopamine transporter imaging in the evaluation of Parkinson's disease.
2. Explain the role of nuclear imaging in the management of patients with temporal lobe epilepsy.
3. A patient has had fever for 20 days and other clinical features of sepsis, but no site of infection could be found. How can nuclear imaging help in the management of this patient?
4. Describe the role of PET/CT in the treatment response evaluation of lymphoma.
5. Describe the concept behind GFR measurement by plasma clearance and urinary clearance with suitable diagrams.
6. A patient with multiple skeletal metastases from follicular carcinoma of thyroid has undergone total thyroidectomy. The patient has been complaining of back pain for 6 months. Describe a management plan for the patient.
7. Give a brief description of nuclear imaging options available for diagnosis of pancreatic neuroendocrine tumours.
8. What is image-guided radiotherapy? How does it help in the management of patients with malignancy?
9. Describe the role of FDG PET/CT in the management of gastric malignancy.
10. Describe the clinical features of Graves' orbitopathy and describe its significance in relation to I-131 treatment.

M.D. DEGREE EXAMINATIONS

NUCLEAR MEDICINE

Paper IV - Recent advances in Diagnostic and Therapeutic Nuclear Medicine

Time: Three Hours **Maximum Marks: 100**

Answer all the following questions: **(10 x 10 = 100 marks)**

1. Explain the emerging role and limitations of sentinel lymph node imaging in oral cavity squamous cell carcinoma.

2. Enumerate the roles of artificial intelligence in nuclear imaging. What are the possible implications of texture analysis in nuclear oncological imaging? (4 + 6)

3. Describe the benefits of a hybrid PET/MR system in oncological imaging? What are the limitations of PET/MR that deters its extensive use? (6 + 4)

4. Compare and contrast cardiac specific gamma cameras and conventional gamma cameras for cardiac imaging.

5. Write short notes on a. Cerenkov imaging, b. Nanoparticles in Nuclear imaging. (5 + 5)

6. Describe the characteristics of Zr-89 and its applications in imaging.

7. How has Ga-68 PSMA scan impacted the management of prostate cancer patients?

8. What is theranostics? Explain the concept with suitable examples. (2 + 8)

9. What is coronary flow reserve (CFR)? How can nuclear imaging help measure CFR? What is the implication of CFR in the management of coronary artery disease? (2 + 4 + 4)

10. Describe how evaluation of cardiac dyssynchrony helps in the management of patients with heart failure.

Annexure 1 (Part A)

KEY-CAPABILITIES IN THE PRACTICE OF NUCLEAR MEDICINE	
1	Radiation physics and instrumentation
2	Radipharmacy
3	Radiation safety
4	Biostatistics
5	Concepts in management
6	Diagnostic Nuclear Medicine
7	Therapeutic Nuclear Medicine
8	Recent advances in nuclear medicine

S.No	Key capabilities	Minimum expected level of performance at time-points					
		6 m	1 yr.	1.5 yrs.	2 yrs.	2.5 yrs.	3 yrs.
KNOWLEDGE AND SKILLS							
1	**Radiation Physics and Instrumentation**						
	Decay calculations, Shielding calculations, Generator Yield calculations	4					
	Dose calibrator: Operation and quality control	3	4				
	Survey meter/Contamination monitor/Pocket dosimeter: Operation	3	4				
	Well counter: Operation and quality control	2		3	4		
	Gamma camera: Basic operation (switching on/off, homing, movement of heads and couch, creation and transfer of files)	2		3	4		
	Gamma camera: Acquisition of planar (dynamic/spot/whole body), SPECT, SPECT/CT, and gated images. Reconstructing and processing of images (planar, SPECT, and SPECT/CT)	2		3	4		
	Gamma camera: Performance characteristics, Quality control, and Maintenance	3		4			
	PET/CT: Basic operation (switching on/off, creation and transfer of files)		2	3	4		
	PET/CT: Acquisition of whole body and regional PET/CT. Reconstructing and processing of images (planar, SPECT, and SPECT/CT)		2		4		

S.No	Key capabilities	Minimum expected level of performance at time-points					
		6 m	**1 yr.**	**1.5 yrs.**	**2 yrs.**	**2.5 yrs.**	**3 yrs.**
	PET/CT: Performance characteristics, Quality control, and Maintenance		3		4		
2	**Radiopharmacy**						
	Receipt of radiopharmaceuticals	2	3				
	Elution of Mo-99/Tc-99m generator	2		3	4		
	Labelling, quality control, and dispensing of Tc-99m radiopharmaceuticals (MDP, MIBI, etc.)	2		3	4		
	Dispensing of PET radiopharmaceuticals		2	3	4		
	Elution and preparation of Ga-68 labelled radiopharmaceuticals		1		2	3	
3	**Radiation safety**						
	Radiation survey (Area survey, Wipe test)		1		2	3	4
	Radiation waste management		1		2	3	4
	Management of radiation emergencies		1		2	3	4
4	**Biostatistics**						
	Basic concepts in biostatistics	1					
	Counting statistics: Errors in measurement		1				
	Research methodology	3				5	

S.No	Key capabilities	Minimum expected level of performance at time-points					
		6 m	**1 yr.**	**1.5 yrs.**	**2 yrs.**	**2.5 yrs.**	**3 yrs.**
	Statistical analysis	1			2	3	4
5	**Concepts in Management**						
	Management concepts and organisational behaviour			1			
	Accounting and Managerial economics			1			
	Concepts in human resource management			1			
	Quality management			1	2		
6	**Diagnostic Nuclear Medicine** Clinical Nuclear Medicine: Indications, Patient preparation, Acquisition, Processing, and Interpretation						
	Musculoskeletal system: Bone and bone marrow scintigraphy	1		2	3		4
	Endocrine including Thyroid	1		2	3		4
	Nuclear cardiology (SPECT): ERNA, Stress myocardial perfusion scan, myocardial viability	1		2	3		4
	Nuclear cardiology (PET): Myocardial viability, cardiac inflammation study			1		3	4
	Nervous system (SPECT): Epilepsy, stroke, dementia, movement disorders, cisternography	1		2	3		4

S.No	Key capabilities	Minimum expected level of performance at time-points					
		6 m	**1 yr.**	**1.5 yrs.**	**2 yrs.**	**2.5 yrs.**	**3 yrs.**
	Nervous system (PET): Epilepsy, dementia, movement disorders			1		3	4
	Gastrointestinal system including Hepatobiliary: Motility studies, Hepatobiliary scintigraphy for biliary atresia, leak, etc.	1		2	3		4
	Genitourinary system: Renal (dynamic scan, cortical scan, reflux scan), Scrotal scintigraphy	1		2	3		4
	Pulmonary system: Ventilation/Perfusion scan	1		2	3		4
	Oncology: FDG PET/CT		1		3		4
	Oncology: Other radiopharmaceuticals - Somatostatin receptor imaging, PSMA, etc.			1		3	4
	In-vitro studies			1		3	4
7	**Therapeutic Nuclear Medicine**						
	Clinical evaluation and management of thyroid cancer, thyrotoxicosis, bone pain palliation, neuroendocrine tumour, and prostate cancer patients		1		2		3
	Administration of radiopharmaceuticals for therapy		1		2		

S.No	Key capabilities	Minimum expected level of performance at time-points					
		6 m	**1 yr.**	**1.5 yrs.**	**2 yrs.**	**2.5 yrs.**	**3 yrs.**
8	**Recent advances in diagnostic and therapeutic nuclear medicine**						
	Recent advances in instrumentation and radiopharmacy			1			
	Recent advances in image processing				1		
	Recent advances in therapeutic nuclear medicine					1	
	Artificial intelligence in nuclear medicine						1
	Principles and practice of other imaging modalities such as ultrasound, MRI, optical, fluorescence imaging, etc.					1	

Annexure 1 (PART B)

Core ideas in the practice of key-capabilities

S.No	Core ideas in the practice of key-capabilities	Semester					
		Sem 1	**Sem 2**	**Sem 3**	**Sem 4**	**Sem 5**	**Sem 6**
1	● Radiation Physics ● Physics and Instrumentation of nuclear medicine equipment ● Radiochemistry and Radiopharmacy	1					
2	● Radiobiology ● Principles and application of Radiation dosimetry ● Radiation safety and protection ● Biostatistics ● Basic concepts in management		1				
3	Clinical Nuclear Medicine imaging principles and applications in ● musculoskeletal system ● Endocrinology ● Gastrointestinal system ● Genitourinary system ● Cardiovascular system ● Pulmonary system			1			

S.No	Core ideas in the practice of key-capabilities	Semester					
		Sem 1	Sem 2	Sem 3	Sem 4	Sem 5	Sem 6
4	Clinical Nuclear Medicine imaging principles and applications in ● Neurology ● Oncology ● Infection and inflammation imaging In-vitro procedures and Radionuclide therapy				1		
5	Recent advances in ● instrumentation hardware and related software ● radiopharmaceuticals ● radiation safety practices and regulations ● image processing and reporting ● radionuclide therapy ● recent guidelines ● landmark clinical trials and research studies Artificial intelligence Principles and practice of other imaging modalities such as ultrasound, MRI, optical, fluorescence imaging, etc.					1	

Paper I – Basic Sciences related to Nuclear Medicine

1. Physics – Radiation Physics and Instrumentation

- General: Atomic structure, Nuclear stability, concept of radioactivity and decay, Types of decay, various emissions and their characteristics, Interaction of radiation with matter, Decay schemes of important radionuclides.
- Instrumentation: Gas chambers, Scintillation (solid – organic & inorganic, liquid) – single photon & coincidence imaging, Characteristics of scintillation crystals, Semiconductor detectors, Collimators and their types, Photomultiplier tube, Photodiodes, Pre-amplifier, Amplifier, Analog to Digital Converter, Pulse height analyser, Positioning logic circuit, Display devices, Cerenkov imaging, Bremsstrahlung imaging, etc.
- Applications of gas chambers (Ionisation chamber, Proportional counter and Geiger Muller tube, etc.), Scintillation devices (Gamma probes including thyroid uptake and intra-operative probes, Rectilinear scanner, gamma cameras, well counters, positron emission tomography, etc.), Solid state detection imaging & non-imaging devices, Dedicated imaging systems (preclinical and organ-specific like brain, cardiac, breast, etc.)
- Counting characteristics – Uniformity, Spatial resolution, Contrast (CNR, etc.), Energy resolution, Temporal resolution (dead time and pulse pile up), High count rate capability, etc.
- Types of image acquisition: Gamma imaging – Planar (dynamic, static, whole body), SPECT, ECG gating for planar and SPECT; PET imaging – 2D, 3D, 4D, Whole body & regional, Dynamic – frame & list mode, ECG gating, Time of flight, radionuclide & CT based attenuation correction, etc.; CT – Topogram, Plain, Attenuation map generation, Contrast-enhanced CT (triple phase, Angiography, ECG Gating), etc.
- Total body PET imaging
- Image reconstruction and corrections – Filtered backprojection, Iterative reconstruction, Image filters, artefacts, Scatter and attenuation correction, motion correction, Scatter & Random correction in PET, Collimator Response Recovery
- Miscellaneous topics: Phantoms, Counting statistics, Pulse height spectrometry, Energy spectrum of important radionuclides, Check sources, Contrast agents for CT
- Performance and maintenance of equipment: Quality Assurance and Quality control, NEMA protocols for acceptance testing, Schedule of quality control of various equipment (dose calibrator, survey meter, well counter, Thyroid Uptake Probe, gamma camera, PET, CT, etc.), Accepted limits of various quality control parameters.
- Basic physics of instrumentation and functioning of X-ray, CT, MRI, USG, fluorescence and bioluminescence devices, Autoradiography.
- PACS, RIS, HIS, DICOM, Telemedicine

2. Radiochemistry and Radiopharmacy

- Basics chemistry – chemical reaction – oxidation, reduction, bonds – ionic, covalent and covalent coordinate bonds, acids, bases, pH, Ionic strength, buffers, osmolarity, osmolality, normality, instruments, periodic table, etc.
- Tracer kinetic modelling – Dilution, Membrane transport – passive diffusion, facilitated diffusion, Flow, Perfusion, Uptake, Extraction fraction, Clearance, Flux, Compartmental analysis, rate constants, receptor binding, protein synthesis, etc.
- Production of radionuclides –General - specific activity, impurities, etc.; Nuclear reactor – construction and principle, fission products and neutron bombardment, common reactor-produced radionuclides; Cyclotron - construction and principle, types of cyclotron, targets, common cyclotron-produced radionuclides (F-18, C-11, N-13, etc.); Radionuclide Generators – Equilibrium and its types, Yield of generators, Commonly used radionuclide generators – SPECT, PET and therapeutic radionuclides, Types of generators – solvent extraction, solid column, etc.
- Chemistry of commonly used radionuclides such as Tc-99m, Ga-68, Re-188, etc.,
- Radiolabelling - Chelation, Transchelation, Bifunctional chelates, Radio iodination, Cell-labelling, Antibody-labelling, Radiocolloids, Peptide labelling, Common Tc-99m labelled radiopharmaceuticals, Synthesis of PET radionuclides – FDG, [18F]F-DOPA, N-13 Ammonia, etc.
- Quality control of radiopharmaceuticals – Physical appearance, Chemical purity, Radiochemical purity, Radionuclidic purity, Testing of Sterility, Apyrogenicity, and Toxicity
- Mechanisms of localisation of tracers
- Classification of tracers – F-18 labelled, Non-FDG F-18 labelled, Ga-68 labelled, Cu-64 labelled, Radiocolloids, radiopharmaceuticals pertaining to specific systems or similar radiopharmaceutical category.

3. Radiobiology

- Cell and its structure, Cell cycle, Cell multiplication – mitosis and meiosis and their phases, DNA replication and repair
- Direct and Indirect action of radiation, DNA damage and repair (single and double strand repair) – Mutation and its types, Chromosomal aberration, apoptosis
- Cell survival curves – Cell culture techniques, Dose response curves following exposure to radiation - Linear non-threshold model, Linear quadratic model, Effect of oxygenation – Oxygen enhancement ratio, Radiation sensitizers, Radiation protectors, Bystander effects
- Effects of radiation – Deterministic (Acute radiation syndrome, Lethal Dose-50, Detection of radiation exposure – e.g. comet assay, cataractogenesis, effect on embryo & foetus, etc.) and

Stochastic (carcinogenesis, hereditary diseases, etc.)

- Quantities - Radiation weighting factor, Tissue weighting factor, Linear Energy Transfer, Relative Biological effectiveness, Dose and Dose Rate Effectiveness Factor, Target organ, critical organ, etc.
- Miscellaneous – Occupational Radiation exposure and doses in nuclear medicine and long term effects, Radiation hormesis, etc.

4. Radiation safety

- Units of Radioactivity and related measurements (Activity, Exposure, Kerma, Air-kerma, Absorbed dose, Equivalent dose, Effective dose, Dose equivalent, Annual Limit of Intake, Specific Gamma ray dose constant, etc.)
- Dosimetry – Medical Internal Radiation Dosimetry, Software for dosimetry calculation, Application of dosimetry techniques in diagnostic and therapeutic settings, Area & surface monitoring, Personnel monitoring (pocket dosimeters, film badge, Thermoluminescent dosimeter, etc.),
- Radiation symbols, Types of package, Testing of package, Transport index, etc.
- Recommendations and Regulations - International Commission for Radiological Protection, International Atomic Energy Agency, Atomic Energy Regulatory Board; Occupational hazard and prescribed dose limits
- Planning of nuclear medicine facilities (Radioimmunoassay, Gamma camera, SPECT/CT, PET/CT, Cyclotron, therapy ward, etc.), Types of radioactive areas and labs, Half-value layer, shielding requirement and calculations, etc.
- Radiation waste management – storage and disposal methods, management of death of patient with internally administered alpha and beta emitters/long half-life, etc.
- Radiation accidents (eg. Fukushima, Chernobyl, Hiroshima & Nagasaki, Marshall Islands, etc.), Radiation emergencies – spills, misadministration, and their management
- Paediatric dose considerations (e.g. EANM paediatric dosage card), Image Gently, Image Wisely, Choose Wisely

5. Biostatistics

- Measures of central tendency (Mean, Median, Mode), Measures of dispersion (Skewness, Kurtosis, Variance, Standard deviation, Co-efficient of variance), Standard error of the mean
- Normal & Poisson distribution, confidence intervals, etc.
- Errors in measurement – Random & Systematic (bias)
- Types of research studies - Descriptive (Cross-Sectional, case report, case series) & Analytical/Experimental (Case control study, Cohort study, Randomised control trial)
- Others: Measures of diagnostic accuracy test (Sensitivity, Specificity, Positive & Negative Predictive values, Accuracy), Odds Ratio, Chi square test, Comparison of means (Independent

and paired t tests), Analysis of Variance (ANOVA), Correlation & Regression, Univariate & Multivariate analysis, Parametric & Non-parametric data and tests, Pre- & Post-test likelihood, Likelihood ratio, Receiver Operating Curve analysis, p-value, Alpha & Beta errors, Bland-Altman analysis, Life table & Kaplan Meier Survival analysis, etc.

6. Concepts in Management

Management concepts and organisational behaviour

Accounting and Managerial economics

Concepts in human resource management

Quality management

Paper II – Clinical Nuclear Medicine - part I

1. Musculoskeletal system

- Radiopharmaceuticals – Older radiopharmaceuticals, Diphosphonate compounds, F-18 NaF, and newer tracers including mechanism of localisation and tracer kinetic modelling.
- Types of acquisition – Gamma camera – Planar dynamic, static, whole body, additional views (oblique, arms abducted, frog-leg, pelvic caudal view, pinhole, etc.); Dual phase, Triple phase, Four phase and Five phase acquisitions, SPECT, SPECT/CT; Whole body F-18 Sodium Flouride PET/CT
- Physiological uptake, normal findings and variants, paediatric skeleton
- Neoplastic diseases of bone
- Malignant: Primary tumours and metastatic evaluation
- Benign tumours – osteoid osteoma, cysts, and others
- Bone marrow imaging
- Trauma and others - Fractures, collapse, spondylolisthesis, Stress fractures, shin splints, Osteogenesis imperfecta, Manchausen's syndrome, Condylar hyperplasia
- Vascular - Avascular necrosis, Legg-Calve-Perthe's disease, Bone infarcts, Graft viability
- Metabolic diseases - Pagets' disease, Osteoporosis, Osteomalacia, Osteopetrosis, Adynamic metabolic bone disease, Fluorosis, Hyperparathyroidism, Thyroid acropachy, Pachydermoperiostosis, Fibrous dysplasia, Metabolic bone disease of renal failure, Renal osteodystrophy, Dystrophic and metastatic calcification, tumoural calcinosis, myositis ossificans, non-skeletal uptake - polymyositis, liver, lung, post-injection, and others
- X- ray, surface & volume rendered CT, MRI, Whole body counter, DEXA
- Quantification: SPECT SUV, SI index, Ratios, Bone index, 24 hour uptake

2. Nuclear Thyroidology

- Radiopharmaceuticals: Tc-99m pertechnetate, I-123, I-124, I-131, Tc-99m MIBI, Tc-99m Tetrofosmin, Tl-201 Thallium chloride; For medullary thyroid cancer – F-18 FDG, Radiolabelled SSTR analogues, etc.

- Acquisition: Thyroid scan – Dynamic, Static (anterior and anterior obliques), marker views, pinhole, SPECT and SPECT/CT, PET/CT, Perchlorate discharge test, Thyroid uptake (using probe, camera-based); Thyroid cancer: Whole body, spot, SPECT and SPECT/CT
- Processing and quantification, normal and abnormal values for: Thyroid scan – Pertechnetate uptake, Thyroid parotid ratio, 24 hour iodine uptake, perchlorate discharge at 1 hour, etc.

Benign –

- Congenital anomalies of thyroid – agenesis, dysgenesis, thyroglossal cyst, ectopic, congenital hypothyroidism & dyshormonogenesis
- Thyrotoxicosis – types of thyrotoxicosis and clinical features, orbitopathy, interpretation of hormone and antibodies, thyroiditis and its types, role of USG, Thyroid scan and uptake, subclinical thyrotoxicosis
- Treatment of thyrotoxicosis – role of medical management (anti-thyroid drugs, cold iodine, steroids, lithium, beta blockers, etc.), thyroid storm & its management, Radioiodine treatment (selection criteria for radioiodine, calculation of dose, adjuvant drugs, orbitopathy, paediatric consideration, thyroxine replacement & follow-up), thyroxine in pregnancy, role of surgery in thyrotoxicosis management. Non-toxic multinodular goiter management.

Malignant –

- Differentiated thyroid cancer of follicular origin
    - Nodule assessment – USG, FNAC, Thyroid scan
    - Surgery – staging, types of thyroidectomy, types of lymph node dissection, post-operative complications and management including hypocalcaemia and recurrent laryngeal nerve injury. Surgery for metastasis
    - Post-operative risk assessment: histopathology, role of whole body radioiodine scans, ultrasound, Thyroglobulin & Anti-Tg antibodies, TSH & rhTSH, calculation of treatment dose, spacing, TSH suppression, and follow-up.
    - TENIS, role of PET/CT, Re-differentiation therapy and other therapy
    - Role of radiotherapy, chemotherapy and newer treatment methods.
- Poorly differentiated / Anaplastic
- Medullary thyroid cancer – Staging, imaging and treatment
- Lymphoma / metastasis

3. Endocrine system (other than Thyroid)

Adrenal cortical imaging:

- Radiopharmaceuticals: I-131 labelled NP-59, I-123, I-131, In-111 and Tc-99m labelled LDL, C-11 Etomidate & Metomidate, 131 Metyrapone, F-18 FDG, etc.
- Indication, protocol, and Image interpretation.
- Image interpretation of CECT- Adrenal protocol

Neuroendocrine imaging:

- Types of neuroendocrine tumours and their characteristics, staging and grading
- Radiopharmaceuticals: I-123 & I-131 mIBG, C-11 Epinephrine, C-11 Hydroxyephedrine, SSTR tracers, Tc-99m DMSA (V), Peptide tracers such as bombesin, Amino-acid derivatives, etc.
- Diagnostic and therapeutic role of nuclear medicine in the management of neuroendocrine tumours
- NET-PET scoring and its implications
- Endocrine emergencies in NET

Parathyroid:

- Radiopharmaceuticals: Tl-201 Thallium chloride, Tc-99m MIBI, Tetrofosmin, C11-methionine, etc.
- Indications and types of hyperparathyroidism, clinical features and biochemical parameters, other imaging modalities, acquisition protocol - Dual phase imaging, Dual tracer imaging (Tc-99m pertechnetate and I-123), SPECT, SPECT/CT
- Image interpretation, false positives & negatives, identification of superior & inferior (MIPS), ectopic locations, brown tumours, Radioguided surgery

4. Nuclear Cardiology

Radiopharmaceuticals and mechanism of localisation: Tl-201 Thallium chloride, Tc-99m labelled MIBI, Tetrofosmin, Teboroxime, NOET, etc., O-15 H20, Rb-82, N-13 Ammonia, F-18 FDG, C-11 palmitate, I-123 MIBG, C-11 Hydroxy Ephedrine, Tc-99m pyrophosphate, In-111 antimyosin antibodies, Tc-99m Annexin V, F-18 Sodium Flouride

Concepts:

- Stress testing – indications & contra-indications, types (physical – treadmill/ bicycle ergometer; pharmacological – chronotropic / vasodilator; miscellaneous), protocols (including end points), preparation, evaluation of adequacy of stress
- ECG Gating and gating protocols
- Stress-Rest protocols (including Rest-stress / Stress-rest, Stress only and one and two day protocols) Myocardial viability assessment
- Risk factors for coronary artery disease, Endothelial dysfunction, Fractional Flow Reserve (FFR), Coronary flow reserve / Myocardial blood flow, Epicardial Adipose Tissue, Coronary calcium score
- Equilibrium and first pass radionuclide angiography
- Acquisition techniques for SPECT and PET, reconstruction methods, compensation for attenuation & scatter, newer reconstruction algorithms for compensation of resolution.

- Processing and interpretation: Various quantitation software and their relative performance, Re-orientation of axis; generation of short axis, and long axis slices, vertical and horizontal; visual wall motion and thickening analysis, quantitation of perfusion and wall motion (segmentation, SSS, SRS, SDS, Polar plot, wall motion & thickening analysis, calculation of ventricular volumes & myocardial mass, dyssynchrony analysis, CFR, etc.), Fusion imaging (MPI SPECT/CTCA)

Topics

- Coronary artery disease - Chronic stable angina, Acute MI setting and follow-up, Post CABG / Percutaneous Intervention, Myocardial viability assessment, Women, Evaluation of patients at high risk for CAD – Diabetics, CKD, Hypertension, chemotherapy-induced toxicity, etc., Peri-operative risk assessment, Vulnerable plaque imaging
- Cardiomyopathy and Cardiac failure
- Cardiac transplantation
- Cardiac innervation
- Shunt studies
- Others: TMT, ECHO and stress ECHO, CTCA, Cardiac MRI, Angiography and Revascularisation techniques (PCI and CABG)

5. Nervous system

- Tracers –
    - Perfusion: Xe-133, I-123 IMP, Tc-99m HMPAO & ECD, O-15 water, C-11 CO & CO2, etc.
    - Metabolism: C-11 amino acid, F-18 FDG, Dopaminergic, etc.
    - Receptor – Serotonin, GABA, etc.
    - Dementia-related – amyloid, tau imaging, metabolic and perfusion imaging tracers
    - Miscellaneous - GHA, MIBI, Cisternography, Neuroinflammation (TSPO), etc.
- Concepts – rCBF, Cerebral flow reserve, tracer kinetics – receptors,
- Epilepsy – Refractory & temporal lobe epilepsy, Ictal, post-ictal & interictal SPECT, PET, SISCOM, SPM
- Dementia – types of dementia & characteristics, role in Alzheimer's disease (tracers and implications), role of NM in mild cognitive impairment & drug trials
- CVA – Carotid artery stenosis (Acetazolamide study & balloon occlusion study for cerebral flow reserve), Role of perfusion & metabolism in stroke,
- Movement disorders – aetiology, tracers, role of NM in movement disorders
- Tumour – Primary CNS lymphoma, Primary CNS tumours (meningioma, astrocytoma, glioblastoma), Recent WHO classification, Metastatic tumour
- Psychiatry – Schizophrenia, mood disorders, etc.
- Cisternography – techniques and indications (CSF leak, hydrocephalus)

- Brain death – DTPA, Perfusion imaging
- Neuroinflammation
- Role of PET/MRI

6. Gastrointestinal and Hepatobiliary system

Gastro-intestinal

- GI motility – Oesophageal transit, Gastro-oesophageal reflux, gastric emptying, small and large intestine motility studies (Indication, tracers, type of meal, procedure, study interpretation and quantification, normal values), other investigations including manometry, metallic bead transit, capsule endoscopy, etc.
- GI bleed – indication, tracers, study procedure and interpretation
- Ectopic gastric mucosa – Indications (Meckel's diverticulum and enteric duplication cyst), tracers, study procedure and interpretation
- Salivary - indication, study procedure, interpretation & quantification
- Miscellaneous - Protein losing enteropathy and chylous ascites, Pleuroperitoneal shunt study, LeVeen shunt study, Inflammatory bowel disease – tracers and study procedure

Hepatobiliary

- Tracers - Sulphur colloid, IDA derivatives, labelled RBC, Tc-99m GSA, etc.
- Indications, procedure, and interpretation of:
    - Space occupying lesion - Differentiation of FNH, adenoma & haemangioma, HCC, metastasis
    - Hepatic function – Hepatic extraction fraction and excretion ratio, functional residual volume assessment, cirrhosis, porto-systemic shunt assessment before TARE
    - Biliary tract – choledochal cyst, neonatal cholestasis (differential diagnosis, Ursodeoxycholic acid / Phenobarbitone priming, procedure, interpretation, diagnostic performance, and other methods including biopsy and peropertive cholangiogram), biliary fistula, stricture, leak, bilioma, cholangitis, acute and chronic cholecystitis – calculous and acalculous, functional diseases of biliary tract – GBEF, Sphincter of Oddi syndrome), Interventions (sincalide, morphine and fatty meal)

7. Genitourinary system

Nuclear Nephro-Urology

- Tracers – glomerular, tubular, and cortical agents
- Renogram – Well-tempered renogram, furosemide dose and protocols, ACE inhibitor/Angiotensin receptor antagonist/exercise/aspirin renogram, generation of renogram curve and fallacies (background correction, renal depth estimation, etc.), types of renogram curves and quantitative parameters (Tmax, diuretic T1/2, T20 to max/3 min ratio, transit times, NORA, etc.), deconvolution analysis, camera-based estimation of clearance of Tc-99m DTPA, I-131 OIH, and Tc-99m EC

- Cortical imaging – indication, procedure, interpretation, and comparison to ultrasound
- Obstructive renal disease – calculous & non-calculous, antenatal hydronephrosis, role of IVU, MCU, RGP, CT & MR urography, renogram, GFR measurement (concept and methods) and estimation; Renovascular hypertension – aetiology, presentation, diagnostic methods, role of renogram and management; UTI – presentation, diagnosis & management, reflux disease & role of radionuclide cystogram (direct & indirect); congenital renal anomalies; Chronic kidney disease – clinical features, diagnosis and management; Transplant evaluation – donor evaluation and post-transplant – complications, diagnosis and evaluation
- Malignancies of kidney and urinary tract

Reproductive system

- Hysterosalpingography
- Scrotal scintigraphy (Testicular torsion vs infection, viability of testis)

8. Pulmonary system

Tracers:

- Ventilation – Xe-133, Kr-81m, Technegas, Pertechnegas, Tc-99m DTPA aerosol, Galligas, etc.
- Perfusion – Tc-99m MAA

Indications, procedure, and interpretation of:

- Acute pulmonary embolism – procedure and interpretation, PIOPED criteria, role of SPECT/CT
- Pre-surgical evaluation prior to lung surgery
- Chronic obstructive pulmonary disease – Tc-99m DTPA clearance study
- Interstitial lung disease
- Ciliary dyskinesia – tracheal, and rhinoscintigraphy

Paper III – Clinical Nuclear Medicine - part II

1. Oncology - Imaging

Tracers:

- Metabolic
    - Glucose –11C-Glucose, 18F-FDG, etc.
    - Amino acid – 11C-Methionine, 18F-FACBC, 18F-F-DOPA, 18F-Dopamine, 18F-FET, 11C-5-HTP, 18F-FTP, etc.
    - Other -131I-NP59, etc.
- Proliferation
    - Nuclear - 18F-FLT, 18F-labelled flouro-arabinofuranosyl thymine analogues, 124I-iododeoxyuridine (IudR), etc.
    - Cell membrane - 11C-Choline, 18F-Flourocholine,
- Angiogenesis – Tc-99m – RGD peptide, 89Zr-DFO-Bevazizumab, etc.
- Receptor – SSTR, GRPR, GLP-1, VIP, Androgen and Oestrogen receptors, 131I & 123I-

labelled mIBG, Tumour microenvironment tracers: FAPI, CXCR4 imaging, etc.

- Apoptosis –99mTc-Annexin V
- Hypoxia – Nitroimidazole group of tracers (18F-MISO, FAZA, 123I-IAZA, etc.) and Thiosemicarbazone group (62Cu-ATSM & PTSM), etc.
- Labelled antibodies – PSMA, CEA, TAG-72, Verluma, cG250, CD20, EGFR, HER1&2, etc.
- Bone imaging – 99mTc-MDP, [F-18]NaF
- Non-specific: 99mTc-labelled MDP, MIBI, DMSA(V), 68Ga-citrate, etc.
- Sentinel lymph node – Tracers, indications, injection techniques, role of SPECT/CT, clinical utility, imaging & probe-based detection, comparison with dye, reverse axillary mapping

Indications

- Role of nuclear medicine imaging (gamma imaging, PET/CT & PET/CECT and PET/MR) in the management of benign tumours and malignancies such as head & neck, lung, oesophagus, stomach, colon, ovary, cervix, musculoskeletal malignancies, etc. – Initial and subsequent treatment evaluation (NCCN, AJCC and other relevant staging systems), Treatment response (Interim and end of treatment)
- Response assessment criteria in solid organ malignancies. Response assessment for immunotherapy, Prognostication and Follow-up of various malignancies.

Special topics:

- Poorly differentiated / Anaplastic thyroid carcinoma- Staging, imaging and treatment
- Medullary thyroid cancer – Staging, imaging and treatment, Role of PET-CT
- Lymphoma – staging, treatment response evaluation and criteria, recurrence evaluation
- Lung – Pulmonary nodule evaluation, Respiratory gating (4D PET)
- Breast – Scintimammography and PEM for screening
- Quantification – SUV & its subtypes, MTV, TLG, SAM, N SAM, Ratios and scores, RECIST, PERCIST
- FDG avidity in various tumours
- Dual time point imaging, Dual tracer PET imaging, PET/CT enteroclysis
- Contrast-enhanced CT, PET/MRI
- Theranostics & Dosimetry, Post-therapy imaging
- PET-guided biopsy
- RT planning, Radioguided surgery

2. Infection and Inflammation Imaging

- Musculoskeletal Inflammation and infection - Spondylo-arthropathies, enthesitis, tendinitis, Periostitis, Osteitis, Osteomyelitis, Malignant otitis externa, Synovitis, Arthritis, bursitis, SAPHO syndrome, Prosthetic infection
- Cardiac Infection & Inflammation: Sarcoidosis, Amyloidosis, myocarditis, endocarditis, prosthetic valve and pacemaker infection

- Nervous system – Brain - HIV-associated, Toxoplasmosis, Encephalitis, sarcoidosis, tuberculoma, Neurocysticercosis

2. In-vitro Nuclear medicine procedures and Miscellaneous

In-vitro Nuclear Medicine procedures:

- Haematological – intrinsic factor deficiency, Ferrokinetic studies, Erythyrocyte – survival studies, RBC and volume estimation, Blood volume / plasma volume estimation
- Urea breath analysis test
- Protein losing enteropathy
- Radioimmunoassay, Immunoradiometric assay and other immunoassays (ELISA, CLIA)
- Renal clearance studies – Radionuclide urinary and plasma clearance studies with EDTA, DTPA, iothalamate, etc., MAG3 and EC clearance

Miscellaneous imaging procedures:

- Indications, tracers, procedure, and clinical utility of Dacryoscintigraphy, Lymphoscintigraphy, Radionuclide Venography, etc.

3. Therapeutic Nuclear Medicine

- Radionuclides – physical characteristics (emissions, energy, range, decay scheme, half-life), production - Beta particles, Alpha particles, Conversion electrons, Auger electrons
- Radiopharmaceuticals / methods –
    - As salts – 131I-sodium iodide, 223Ra-chloride, etc.
    - Ligands to receptors - SSTR, mIBG, etc.
    - Radio-immunotherapy – (including biotin-avidin use) - anti-CD20, PSMA, etc.
    - As particles – lipiodol, microspheres, colloids
    - Interstitial therapy - I-125 pellets for carcinoma of prostate
    - Skin patch – skin malignancies
- Indications:
    - Benign: Thyrotoxicosis, Synovitis, stents, polycythaemia vera, etc.

      Treatment of thyrotoxicosis – role of medical management (anti-thyroid drugs, cold iodine, steroids, lithium, beta blockers, etc.), thyroid storm & its management, Radioiodine treatment (selection criteria for radioiodine, calculation of dose, adjuvant drugs, orbitopathy, paediatric consideration, importance of contraception, pregnancy & lactation, thyroxine replacement & follow-up), thyroxine in pregnancy, role of surgery in thyrotoxicosis management. Non-toxic multinodular goitre management.
    - Malignant:

      Differentiated thyroid cancer of follicular origin

      Nodule assessment – USG, FNAC, Thyroid scan

      Surgery – staging, types of thyroidectomy, types of lymph node dissection, post-operative complications and management including hypocalcaemia and recurrent

laryngeal nerve injury. Surgery for metastasis

Post-operative risk assessment: histopathology, role of whole body radioiodine scan and treatment, ultrasound, Thyroglobulin & Anti-Tg antibodies, TSH & rhTSH, calculation of treatment dose, spacing, TSH suppression, and follow-up.

Role of radiotherapy, chemotherapy.

Guidelines - NCCN, ATA, etc.

Neuro-endocrine & others – Pheochromocytoma, paraganglioma, carcinoid, gastro-intestinal & pancreatic neuroendocrine tumours, medullary thyroid cancer, neuroblastoma - Treatment options in Neuroendocrine carcinoma - Selection of patients, biochemical evaluation, Choice of radiopharmaceutical (diagnostic and therapeutic agents) and determination of therapeutic dose, procedure of administration, post-therapy imaging, complications and follow-up); Lu-177 DOTATATE Therapy, Various PRRT Regimens: Sandwich, Dual, Tandem

Hepatocellular carcinoma – Trans-arterial radionuclide embolisation (TARE), Pre-therapy evaluation – Selection of patients, biochemical evaluation, Angiogram, Evaluation of arteriovenous shunts (Tc-99m MAA); Choice of radiopharmaceutical and determination of therapeutic dose, procedure of administration, post-therapy imaging, complications and follow-up

Lymphoma - Selection of patients, biochemical evaluation, Choice of radiopharmaceutical (diagnostic and therapeutic agents) and determination of therapeutic dose, procedure of administration, post-therapy imaging, complications and follow-up)

Skin malignancies – skin patches

Malignant pleural and peritoneal effusion – radiocolloids – indication and procedure

Bone pain palliation – indication, radiopharmaceuticals, mechanism of action, selection of patients, patient preparation, procedure, adverse effects, and follow up.

Prostate cancer: Lu-177 PSMA Therapy - Indication, selection of patients, patient preparation, procedure, adverse effects, and follow up.

Paper IV – Recent Advances in Nuclear Medicine

- PET-MRI – Fusion, Hybrid system - Construction and development – interference of PET in MRI and that of MRI in PET, issues with integration, sequential & simultaneous acquisition, MR-based attenuation correction, and clinical applications.
- MRI – basic concepts, contrast-enhanced MRI, Common sequences of MRI – T1w, T2w, T2 Fat Saturated, FLAIR, STIR, Gradient echo, ASL, BOLD, DWI & ADC, DTI, MRS, fMRI, SPIO, etc.

- Newer concepts in Radiopharmacy - Alpha-emitters for therapy, Alternative methods for Tc-99m production, Cu-64, Re-186, Re-188, Zr-89 labelled tracers, CXCR-4 based therapy options, FAPI based therapy options, Newer radiolabelled antibodies, repebodies, peptides, ADAPT scaffold proteins, anti-tumour drugs, etc.; F-18 mFBG
- Newer dedicated imaging systems, Newer reconstruction and compensation methods.
- Myocardial blood flow and reserve
- Cerenkov, Fluorescence and bioluminescence imaging, Flourescence molecular tomography (FMT/CT), Optical coherence tomography (OCT), Multimodality imaging, Nanoparticles
- Expert/Decision support systems for image interpretation – eg. RENEX
- Machine learning techniques, Computer aided diagnosis, Radiomics, Texture analysis, Fractal & Multifractal analysis
- Guidelines Update pertaining to nuclear medicine and molecular imaging, therapy
- Therapy: New radionuclide therapies; Alpha emitters for radionuclide therapy, Thyroid cancer: TENIS, role of PET/CT, Re-differentiation therapy and other therapy including Tyrosine Kinase inhibitors
- Theranostics, Personalised or personalised Nuclear Medicine
- Clinical trials in various areas of nuclear medicine and related fields
- Cost-effectiveness analysis of diagnostic and therapeutic nuclear medicine services

Annexure 1 (Part C)

Learning Objectives - Peripheral Posting of MD Nuclear Medicine Residents

Will be attended by Junior Residents in 2nd and 3rd years
Total Duration - 2 Months (Each posting for 4 weeks)

Background:

The resident will be attending this peripheral only after they pass a test in related theory exam conducted by the parent department. This will help them to achieve the objectives of this posting optimally.
Residents should maintain a log of all the procedures that they observe.

Objectives of peripheral posting in radiodiagnosis:

At the end of radiodiagnosis peripheral posting, the MD (Nuclear Medicine) resident should be able to

- correctly describe the indications for the above-mentioned investigations

- describe the techniques involved in performing the above-mentioned investigations

- To correctly identify and describe abnormal cases in 6/10 opportunities in the relevant areas.

Investigations to be observed:

-Barium swallow, Barium meal study, micturating cystourethrogram, X-rays of bones for fracture and malignancy,

-Ultrasonogram of the thyroid, kidneys, liver, and abscesses.

-CT of the lungs for solitary pulmonary nodules and COPD. CECT of thorax and abdomen – malignancy, CT angiography – pulmonary and renal artery stenosis

MRI – Brain (malignancy, stroke, and epilepsy), osteomyelitis, osteonecrosis

The MD resident will get attendance marked by the faculty-in-charge of the posted section every day and will get a signature on the log of daily activities. The resident will report on time at the section posted and may be involved in the day-to-day activities.

Annexure 2

Procedure	Month/time period		Month/time period		Month/time period	
	Done independently	Assisted	Done independently	Assisted	Done independently	Assisted

Annexure 3

Name of student and semester: Month/year:
Modality: Authorised leaves:
Reporting time: Unauthorised absenteeism:

Example for scoring criteria: (item 3) report quality

Score 0 (does **not attempt** to meet expectations)	Score 1 (Attempting to, but **yet to meet** expectations)	Score 2 (**meets** expectation)	Score 3 (Proficient, independently exhibits responsibility and standards **beyond** minimum expectations)
Consistently incomplete report plus many mistakes, does not attempt to improve	> average mistakes, report left incomplete often, attempts to improve	Minimal occasional mistakes, corresponding to position in learning curve.	Has fluent knowledge of clinically relevant items and report is complete in all aspects - consistently can be approved without correction

	Pl. give a reflection/narrative of your experience during posting, at the back of page (optional)	**0**	**1**	**2**	**3**
	Clinical work				
1	History, clinical examination, safety, patient interaction				
2	Planning/monitoring of imaging, provisional report				
3	Adequacy of literature search/discussion/rationale and report quality				
4	Completeness of records				
5	Completeness of therapy case records done 2 months prior				
	Team work, leadership, communication and attitude				
6	Quality of seminars led by the student/participation in seminars of others				
7	Co-ordination and communication with hospital personnel				
8	Demonstration of responsibility in reducing patient waiting time when scheduling, reporting etc.				
9	Teaching - Shows interest in teaching juniors, Gives appropriate feedback to juniors				
10	Accepts feedback, self-reflects and demonstrates willingness to change				
	Total marks 10*3 = 30 marks				
	Logbook (10 marks)				
	Has this form been discussed with student(yes/no)/ Faculty signature/total				

Date and topic of seminar/case presentation (**score as per criteria* (0/1/2/3/**)	Clarity of idea in student	Communication skill/ aids	Moderator sign/name