NUCLEAR MEDICINE COURSE 11 – 14 MARCH 2025

Day1: Radionuclides & Radiation Protection

Lecture 1: Physics for Nuclear Medicine. Dr Jan Taprogge
This talk covers the fundamental principles of nuclear physics and lays the groundwork for all subsequent talks. Nuclear decay modes and energy levels are explained which form the basis to a solid understanding of the use of radionuclides in nuclear medicine. Furthermore, photon and particle interactions are covered which are essential to gamma camera and PET imaging. As part of the discussion about photon interactions, photoelectric absorption, Compton scatter and pair production are described. In addition, Bremsstrahlung and inelastic radiative interaction are explained.

Lecture 2: Radionuclide Production. Jennifer Robinson
This lecture covers the production of radionuclides for clinical use. The use of charged particle and neutron irradiation are discussed as are the use of nuclear fission and radionuclide generators. Particular emphasis is given to Mo-99 and Tc-99m production including an overview of the emerging alternative production methods.

Lecture 3: Radiopharmaceuticals. Stephen Howell
Facilities and standards for Radiopharmaceutical Manufacture, Preparation of radiopharmaceuticals, Quality control of radiopharmaceuticals, biological behaviour of radiopharmaceuticals and basic chemistry relevant to pharmaceutical production.

Lecture 4: Nuclear Medicine / PET Case Studies. Dr Daniel Levine
Case studies of nuclear medicine, with emphasis on imaging techniques and clinical applications including bone, lung, renal and cardiac imaging, tumour targeting and infection imaging with examples of multi-modality hybrid imaging.

Lecture 5: Radiation Detectors. Dr Dimitra Darambara
This lecture covers the fundamentals of radiation detectors used across nuclear medicine imaging. The principles of gas-filled detectors, scintillation counters, and semi-conductors are covered. The relative advantages of each detector type are compared.

Lecture 6: Radiation Protection in Nuclear Medicine. Dr Allison Craig.
Legislation, justification, optimisation, limitation, room protection and designation of areas, PPE and staff protection, staff monitoring, waste storage, waste disposal, IRMER and patients, and transport.

Day2: Gamma Camera Imaging

Lecture 7: The Gamma Camera. Bruno Rojas
This talk covers the basic design of a gamma camera and the way that the fundamental components allow for the creation of an image. We work through the camera from the collimator, discussing the effect of collimator choice on image resolution and sensitivity, on to the scintillator and its basic requirements through to the photomultiplier tubes and the signal that they generate. We discuss how the PMT signal is used to create an image and a photon energy spectrum through Anger logic, ending on the basic corrections that are needed to turn this raw image into a clinically usable one. The talk builds on those given earlier in the course which introduce these components and the interactions that take place therein and leads into later talks on the clinical uses of the gamma camera.
We recommend Richard Lawson's "The Gamma Camera: A Comprehensive Guide" (IPEM publishing, 2013, ISBN 978 1 903613 53 5) for further reading on the subject.

Lecture 8: Nuclear Medicine Imaging Techniques. Dr Jonathan Gear
General principles, acquisition and processing parameters, acquisition of static and whole body scans, dynamic and gated studies, examples for renal studies and cardiac imaging.

Lecture 9: SPECT Imaging. Dr Jonathan Gear
Introduction to emission computed tomography. SPECT acquisition and filtered back-projection reconstruction methods. Optimisation of SPECT acquisition and reconstruction parameters. Scatter correction, attenuation correction, examples and applications.

Lecture 10: Iterative Reconstruction. Dr Iain Murray
This lecture concerns iterative methods of image reconstruction. The concept of the system matrix is explained and used in a detailed explanation of the MLEM algorithm. The use of prior information in penalised algorithms is also discussed.

Lecture 11: Nuclear Medicine / PET Case Studies. Dr Brent Drake
Case studies of nuclear medicine, with emphasis on imaging techniques and clinical applications including bone, lung, renal and cardiac imaging, tumour targeting and infection imaging with examples of multi-modality hybrid imaging.

Lecture 12: Quality control and performance assessment of gamma camera systems. Dr Allison Craig
Qualitative / quantitative assessment, intrinsic / extrinsic performance, non-uniformity, spatial resolution, energy resolution, spatial distortion, plane sensitivity, count-rate performance, shield leakage, performance assessment in SPECT.

Lecture 13: Image Processing. Dr Iain Murray
An overview of basic image processing techniques to deal with noise and recovery of spatial resolution is given. Techniques include convolution and Fourier filtering; matrix resizing; adaptive filtering techniques.

Lecture 14: Advances in Gamma Camera Technology. Bruno Rojas
Building on the foundations laid out in The Gamma Camera we explore new developments in the field. We cover novel detector types and their potential advantages, novel collimator materials and designs and the resultant gamma cameras that are available on the market thanks to these developments, both for clinical and translational imaging. We also delve into potential future cameras from the more predictable to the potentially revolutionary.

Day 3: PET-CT
Lecture 15: Principles of CT Imaging. Dr Jamie Dormand.
A refresher lecture recapping the basic principles of CT image formation; CT parameters affecting dose and image quality; Advanced CT imaging techniques such as contrast enhancement and dynamic CT.

Lecture 16: PET Instrumentation. Dr Iain Murray
The basic principles of PET instrumentation and design are presented including strategies for dealing with random, scattered and attenuated photons. The use and clinical impact of time-of-flight techniques are discussed. The lecture also covers Quality Control and NEMA testing.

Lecture 17: PET tracer production & molecular targeting. Manoj Ojha.
Overview of PET, PET radiotracers (types, mechanisms of action, development), commonly used PET radiotracers, radiolabelling and quality control, overview of clinical translation – from bench top to GMP environment - and clinical case studies.

Lecture 18: Principles of Tracer Kinetics. Dr Jan Taprogge.
Dynamic PET images can be analysed using kinetic modelling to extract quantitative biological parameters such as the delivery rate of a tracer to a target tissue, the trapping rate of a tracer and the binding potential of a tracer. This talk covers the basic principles of compartmental modelling such as input functions, rate constant determination (including Patlak and Logan plots) and VOI-based vs pixel-wise analysis. Several examples such as cerebral blow flow measurements, F-18 FDG and F-18 FLT are presented and the principles behind the extraction of quantitative biological parameters described. Furthermore, an introduction to kinetic modelling in radionuclide therapy is provided focussing on examples in the literature.

Lecture 19: The Future of Nuclear Medicine. Dr Nabil Hujairi
Nuclear Medicine is going through exciting developments in the era of personalized medicine, using the latest technology in radiopharmaceutical development, hybrid imaging and theranostics. In this lecture, PET-based molecular imaging is used as an example to illustrate the assets and the way forward for Nuclear Medicine, but also to critically reflect on the challenges ahead.

Lecture 20: PET in radiotherapy. Dr Iain Murray
This lecture is an introduction to the use of PET (and SPECT) in radiotherapy planning, in particular for target volume delineation, as well as dose boosting. Practical implementation is discussed alongside an overview of the clinical evidence advocating the use of PET in radiotherapy.

Lecture 21: Advances in PET technology. Dr Iain Murray
The lecture builds on the "PET Instrumentation" talk to cover recent advances in PET technology including the use of silicon photomultipliers, alternative scintillators, motion correction, depth of interaction, monolithic block detectors, and whole-body PET.

Day 4: Dosimetry
Lecture 22: Introduction & the MIRD schema. Professor Manuel Bardies.
Introduction to dosimetry, the MIRD scheme, and the OLINDA software for internal dosimetry.

Lecture 23: Quantitative Imaging. Dr Jonathan Gear.
Various scatter, attenuation and calibration methods are discussed required to achieve gamma camera quantitative imaging for the estimation of the absorbed dose following administration of a radionuclide.

Lecture 24: Absorbed Dose Calculation Algorithms, Professor Manuel Bardies.
The different types of dosimetric approaches (diagnostic and therapy). The different types of radiation transport and energy deposition algorithms: compromise between accuracy and computational speed.

Lecture 25: Applications of Internal Dosimetry. Dr Jonathan Gear.
This lecture covers practical examples demonstrating the application and methodologies of WB Dosimetry, organ dosimetry and tumour dosimetry. Real clinical examples are given and put into context. Scenarios ranging from radiation protection to treatment planning and optimisation are presented.

Lecture 26: Radiobiology for mRT. Paul Gape
This lecture covers non-stochastic effects of radiation in human tissues. Quantitative frameworks to model the effects of radiation are discussed including the linear-quadratic model of cell kill, its application to molecular radiotherapy and the concept of the biologically effective dose.

Lecture 27: Dosimetry in emerging clinical therapies. Dr Allison Craig
The number of molecular radiotherapy treatments is growing. This talk gives an overview of clinical dosimetry applied to these clinical scenarios including a review of dose-response relationships.

Lecture 28: Practical Session. Dr Glenn Flux
Interactive session illustrating the principles of radiation dosimetry in practice.