

Content & Learning Outcomes

MSc Advanced Neuroimaging 2012-13

The following contains a summary of the content of each of the six taught modules on the MSc in Advanced Neuroimaging 2012-13:

Module P1: Introductory Science and Methods (15 credits)

Module P2: Imaging Modalities (15 credits)

Module P3: Advanced Imaging (15 credits)

Module C1: Introduction to Neuroanatomy, Systems and Disease (15 credits)

Module C2: Pathology & Diagnostic Neuroimaging I (15 credits)

Module C3: Pathology & Diagnostic Neuroimaging II (15 credits)

and what we intend the student will have achieved by the end of each, through their attendance of lectures and their own directed study. Reading lists will be distributed at the beginning of the term.

Two further self-directed modules are described similarly in this document. These are the **Library Project (30 credits)** and the **Research Project (60 credits)** and their content will vary according to the choices made by the student.

Upon successful completion of the MSc course, students will have developed a broad knowledge of the principles that underlie advanced neuroimaging techniques and of their application to improving our understanding of normal brain function and clinical disorders of the central and peripheral nervous system. In particular they will:

- *Have a good basic knowledge of neuroanatomy.*
- *Understand the principles and main technical aspects of neuroimaging instrumentation and data acquisition, basic image processing (and identify its need) and image analysis techniques.*
- *Have a good working knowledge of modern methods for scientific and clinical investigation of the human nervous system using neuroimaging.*
- *Be aware of the major recent developments in research in the area of neuroimaging.*
- *Be able to embark upon a successful career in their chosen field of imaging neuroscience research or neuroradiology.*

Module P1: Scientific Basis and Methods (15 credits)

Content Summary

Core Mathematics (CM)	Vectors; Exponentials; Periodic Functions; Complex Numbers; Matrices; 1-D & 2-D Fourier Transforms
Core IT (CIT)	Hardware; System Architecture; Programming Concepts; Operating Systems; Networking; Image Storage; DICOM and PACS; Basic use of MatLab
Core Physics (CP)	Waves; Electricity & Magnetism; Atoms & Light; The Nucleus & Radiation
Principles of Image Formation (PIF)	Image restoration; Analogue-to-digital conversion; Image reconstruction; Image quality & quality correction
Introductory Statistics (S)	Study design; Estimation & Hypothesis testing; Continuous & Categorical Data; Correlation & Regression

Learning Outcomes

Core Mathematics (CM)

At the end of this module, students will be able to demonstrate understanding of and competence in the basic mathematics of imaging science, such as vectors, matrices, exponential functions, periodic functions, complex numbers and Fourier analysis.

Core IT (CIT)

At the end of this module, the students will understand the basic architecture of modern computer systems, hardware and software.

Matlab (ML)

The students will be able to understand, design and code programs in the Matlab programming environment and relating to the Core Mathematics learning outcomes.

Principles of Image Formation (PIF)

At the end of this module the students will be able to describe the basic principles of image formation relevant to modern neuroimaging, the basic concepts of image perception and representation, digital images and basic digital image transformations.

Core Physics (CP)

At the end of this module, students will be able to demonstrate a knowledge of the necessary background physics required for the remaining course units, including essential wave behaviour, electricity and magnetism, atomic structure and radiation.

Introductory Statistics (S)

Students will be able to demonstrate understanding of the basic statistical methods required to carry out independent research in the field of Neuroimaging.

Module P2: Imaging Modalities (15 credits)

Content Summary

Magnetic Resonance Imaging (MRI)	Basic physics; Imaging pulse sequences and contrast; Instrumentation and safety;
Computed Tomography (CT)	Instrumentation/image reconstruction; Image contrast and artefacts; Contrast agents; CT angiography; Dosimetry/safety; MIP; Surface rendering
Radionuclide Imaging (RI)	Basic nuclear physics; Radionuclides,; Imaging systems; Tracer/kinetic studies; Analysis; PET; SPECT
Magnetic Resonance Spectroscopy (MRS)	Chemical shift; Spatial localization; Data processing/quantification; 1H MRS; 31P MRS; Other nuclei; Clinical applications
EEG & MEG (MEEG)	Basic brain electrophysiology; Nature of the EEG & MEG signals; Scalp EEG & MEG measurement & instrumentation; Display and analysis; Correlation with fMRI
X-Ray (XR)	Sources & Detectors; Signal processing; Contrast agents; Clinical procedures; Artefacts; Correction strategies; Safety
Ultrasound (US)	Soundwaves in tissue; Probe operation and design; Signal processing; Flow measurement; Safety.

Learning Outcomes

Magnetic Resonance Imaging (MRI)

At the end of this module the students will be able to describe the physical basis of MRI and common MRI sequences used in the clinic and for research. They will also understand and explain the post-processing tools used for MR angiography, such as maximum intensity projection (MIP).

Students will demonstrate understanding of instrumentation and safety issues. They will also be able to describe the basic aims and principles of quality assurance and quality control applied to image acquisition and image interpretation, to describe test objects and procedures involved in QA and QC, and be able to identify the relevant national and international standards.

Computed Tomography (CT)

At the end of this module the students will be able to understand and describe the physical principles of x-ray computed tomography (CT), scanner technology, dosimetry/safety and simple backprojection for image reconstruction.

Students will be able to understand and explain the processing tools used for CTA, such as maximum intensity projection (MIP), shaded surface displays (SSD) and 3D reconstruction.

Radionuclide Imaging (RI)

At the end of this module the students will be able to describe the theory of radioactive decay and detectors, radiopharmaceuticals and their production, nuclear medicine imaging systems, clinical applications, and PET and SPECT systems.

Magnetic Resonance Spectroscopy (MRS)

At the end of this module, the students will understand the origins of the NMR spectrum, methods of spatial localization and quantitative spectrum analysis strategies. They will be able to describe the main characteristics of spectra from the proton and other NMR visible species and the changes caused by disease.

EEG & MEG (MEEG)

At the end of this module the students will be able to describe the basic electrophysiological, physical and technological principles involved in the generation and measurement of EEG/MEG signals, the spatio-temporal nature of those signals and to discuss their role in neuroimaging.

X-Ray (XR)

At the end of this module the students will be able to describe the theoretical principles and clinical applications of Digital Subtraction Angiography (DSA), its instrumentation, associated dosimetry issues, the post-processing tools used for it.

Ultrasound (US)

At the end of this module the students will be able to describe the theoretical principles of diagnostic ultrasound, instrumentation and signal processing, safety and clinical applications.

Safety aspects of medical imaging

For each of the above modalities, students will be able to describe the safety regulatory framework and governance relevant to clinical and research neuroimaging.

Module P3: Advanced Imaging (15 credits)

Content Summary

Perfusion (P)	Bolus techniques using MR and CT; Arterial spin labelling.
Diffusion & Structural Connectivity (DSC)	Diffusion weighted imaging; Diffusion Tensor Imaging; Quantitative analysis of ADC and FA; Fibre tracking
Morphometry & Volumetry (MV)	Concepts; Global vs local measures; Landmarks; Volumetry; Voxel-based methods
Anatomical Data Fusion (ADF)	Principles and aims of multimodality imaging; Image registration; Longitudinal imaging
Mapping Brain Activity & Networks (MBAN)	fMRI contrast mechanisms; Experimental design & paradigms; Data analysis and statistics; Applications.
Quantitative MR Methods (QMR)	Relaxation theory; Relaxometry; MT theory; MT measurement & qMT; Analysis methods

Learning Outcomes

Perfusion (P)

At the end of this module the students will understand the meaning of different haemodynamic parameters such as relative cerebral blood volume (rCBV), relative cerebral blood flow (rCBF), mean transit time and summary parameters. The student will understand the difference between bolus perfusion techniques (using MR and CT) and arterial spin labeling. They will also have an understanding of arterial input function and deconvolution analysis.

Diffusion & Structural Connectivity (DSC)

At the end of this module the students will have an acquired knowledge of isotropic and anisotropic diffusion in the brain, of the apparent diffusion coefficient (ADC) and fractional anisotropy (FA). They will have an understanding of the b value and how the appearance of grey and white matter and pathological processes are influenced by the choice of b value. They will also be familiar with common artefacts on diffusion weighted images such as T2-shine through and T2-masking effects. They will understand the principles of diffusion tensor imaging and tractography.

Morphology & Volumetry (MV)

At the end of this module, the students will be able to describe the aims of, and methods used to characterize and measure brain shape, and to determine brain volumes based on MRI data. The students will be able to describe some applications from the neuroscience literature, and to perform brain morphometry and volumetry.

Anatomical Data Fusion (ADF)

At the end of this module, the students will be able to explain the aims of image registration and the basic steps involved in the process, and to describe a number of applications of image registration in neuroscience. The students will be able to perform measurements and/or analyses following image registration.

Mapping Brain Activity & Networks (MBAN)

At the end of this module, the students will be able to describe the current understanding of functional activation and the basic mechanisms that underlie its detection using neuroimaging, and in particular BOLD fMRI, and to describe applications from the recent neuroscientific literature and in particular some involving multi-modality integration. The students will be able to design a valid fMRI experiment and analyze the resulting data.

Quantitative MR Methods (QMR)

At the end of this module, the students will be able to describe the theory of MT imaging and MRI relaxometry, relevant pulse sequences, and analysis strategies. They will be able to list the technical challenges, likely benefits and safety concerns for high field MRI.

Module C1: Introduction to Neuroanatomy, Systems and Disease (15 credits)

Content Summary

Neuroanatomy (N)	The cortex; Basal ganglia; Cranial nerves; Skull base & spine; Vasculature; The orbit; Embryology & malformations of the brain & spine
Physiology & Function (PF)	The vestibular system; The somatosensory system; The visual system; The auditory system
Clinical Overview (CO)	Epilepsy; Neurodegeneration; Inflammation & Infection; Stroke; Tumours; Neuromuscular disease
Peripheral Nerves & Muscular Disease (PNMD)	Imaging peripheral nervous system; Imaging muscles; Imaging plexus
Fetal Imaging (FI)	Fetal imaging; Neonatal imaging

Learning Outcomes

Neuroanatomy (N)

At the end of this module the students will be able to identify the important anatomic structures of the brain, skull, and spine. They will understand the vascular supply of the head and spine. The student should be gain anatomical knowledge of white matter tracts and the cranial nerve nuclei in the brainstem. They should be able to name pathological processes which commonly involve the brainstem (ischaemia, demyelination, tumours, neurodegenerative disorders) and be familiar with the clinical syndromes caused by lesions in those locations

Physiology and Function (PF)

At the end of this module the students will be able to understand the physiology of the CNS circulation, and the fundamentals of neuronal excitation, EEG generation and functional systems. The student should be familiar with the anatomy of the visual pathways and field defects cause by lesions in specific locations and be able to name commonly encountered pathology in specific parts of the visual pathway.

Clinical Overview (CO)

Students will be able to describe and explain the clinical presentation of *Epilepsy*, *Tumours* and *Neurodegeneration* in terms of the disruption caused to function within the nervous system.

Peripheral Nerves & Muscular Disease (PNMD)

At the end of this module (or the MSc as a whole) the students will be able to understand the pathophysiology and clinical presentation of peripheral nerves and muscle disorders. They will understand the role of imaging in the clinical setup as well as the role of special techniques such as DTI and MT, qMT.

Fetal Imaging (FI)

The student will be able to differentiate between the appearances of normal neonatal brains and those with neonatal encephalopathy, neonatal hypoxic-ischaemic injury, seizures or stroke. They will demonstrate an understanding of how, why and when different imaging modalities are used for imaging neonates and they will show an awareness of the relevant safety considerations.

Module C2: Pathology & Diagnostic Imaging I (15 credits)

Content Summary

Stroke (S)	Small vessel disease; Treatment of ischaemic & haemorrhagic stroke; Paediatric stroke; MRI of haemorrhagic stroke; CT & MR angiography; Motor recovery; Ultrasound Doppler; Territories; Carotid imaging; Differential diagnosis; Intervention
Inflammation & Infections (II)	CNS infections; Creutzfeldt-Jacob disease; CNS lupus; Neurological vascularitis; Viral; Bacterial; HIV-related disease; AIDS
Demyelination (D)	White matter lesions; Magnetisation Transfer, DTI & Spectroscopy in imaging MS; Spine;
Trauma (Tr)	Clinical aspects; Radiology

Learning Outcomes

Stroke (S)

At the end of this module the student will understand the difference between ischaemic and hemorrhagic stroke and their relative frequency. They will understand the main causes of ischaemic stroke in adults and children and be able to identify collateral pathways in the brain and list and understand the main causes of hemorrhagic stroke including differentiating between subarachnoid and intraparenchymal haemorrhage.

The student will be able to discuss the advantages and disadvantages of MRI and CT in differentiating between ischaemic and haemorrhagic stroke. They will also be familiar with the time course of the radiological appearance of ischaemic stroke on CT and MRI with particular emphasis on diffusion weighted MRI. They will demonstrate familiarity with ischaemic penumbra and be able to name the neuroradiological technique used to define it. They will demonstrate knowledge about the MR appearances of small vessel disease be familiar with the most important of scoring systems aiming to quantify small vessel disease.

The student will be able to discuss the advantages and disadvantages of invasive and non-invasive vascular imaging techniques (CTA, different types of MRA) in the investigation of intra and extra cranial vascular stenosis and be aware of the relative sensitivity of CT and various MR sequences in detecting subarachnoid blood.

Finally, the student will be able to name causes of subarachnoid haemorrhage and have a knowledge of the sensitivity and technical limitations of DSA, CTA and MRA in detecting cerebral aneurysms cerebral AVMs and cerebral vasospasm.

Inflammation and Infections (II)

At the end of this module the student will be familiar with the clinical forms of multiple sclerosis and typical imaging appearance (Mac Donald criteria). They will be able to identify factors which can cause vasculitis of the cerebral vessel (SLE, TB, drug use). They will be familiar with the common neurological manifestations of AIDS and aware of the changing pattern of Neuro-Aids with the introduction of highly active anti-retroviral therapy (HAART).

Demyelination (D)

At the end of this module the students will be able to understand the role of imaging in the clinical setup as well as the role of special techniques such as DTI, perfusion, MT, qMT, and spectroscopy.

Trauma (Tr)

The student will demonstrate familiarity with the epidemiology & life expectancy associated with head trauma and will be able to describe the clinical consequences, management & treatment of head traumas of different severity. They will be able to list several common mechanisms and patterns of injury in both the head and spine and suggest appropriate imaging techniques which are most useful for different types of trauma.

Module C3: Pathology & Diagnostic Imaging II (15 credits)

Content Summary

Tumours (Tu)	Epidemiology; Treatment and management of Metastasis & Brain Tumours; Diffusion- & Perfusion-weighted imaging of tumours; Orbital Tumours; Pituitary Tumours; Imaging adult and paediatric tumours; Pre-operative fMRI; Phakomatosis; Spine pathology
Epilepsy (E)	EEG & source localisation; MEG; Structural MRI, standard & serial imaging; EEG-fMRI; Paediatric epilepsy; Surgical treatment
Neurodegeneration (N)	Parkinson's disease; Creutzfeldt-Jacob disease; Pathology; Alzheimer's disease; Differential Diagnosis; Advanced MR; Surgery

Learning Outcomes

Tumours (Tu)

At the end of this module the student will be able to list the most frequent extra-axial tumours, name congenital conditions associated with extra-axial tumours and name the most frequent intra-axial tumours. They will also demonstrate an understanding of the biological mechanism of glial cell tumours.

Students will be able to identify and differentiate intrinsic low and high-grade, extrinsic, pituitary, orbital, spinal tumours and describe the role of fMRI for surgery planning and post-op follow-up.

Epilepsy (E)

The student will gain familiarity with the clinical form of epilepsy and should be able to name a number of neuroradiological findings encountered in patient with epilepsy such as hippocampal sclerosis, cortical heterotopia, arteriovenous malformations (AVMs), cavernomas, benign and malignant brain tumours.

At the end of this module the students will be able to understand the role of imaging in the clinical setup as well as the role of special techniques such as Volumetry, DTI, perfusion, MT, qMT, and spectroscopy for surgery planning and post-op imaging.

Neurodegeneration (N)

At the end of this module the student will be able to demonstrate understanding of the cellular mechanism and predominantly affected brain regions in Alzheimer's Disease (AD) Multisystem Atrophy (MSA), Motor Neuron Disease (MND) Progressive Supranuclear Palsy (PSP), and olivo-pontocerebellar atrophy. They should also show familiarity with the age of onset and long term prognosis for each of the above diseases.

At the end of this module the students will be able to understand the role of imaging in the clinical setup as well as the role of special techniques such as fluid registration and VBM.

Module 7: Library Project (30 Credits)

Content Summary

Research Methodology	The scientific approach; Mass media and specialist journals; Critical appraisal; Oral Presentation; Scientific writing & avoiding plagiarism; Peer- and self-assessment; Feedback; Chairing discussions; Career development; Productivity & Time-Management
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This module includes taught Research Methods sessions (5 credits) during which students will learn practical skills essential for undertaking independent research. Some of the 15 sessions will be taught, while during most students will present and discuss current journal articles relating to Neuroimaging.

The Library Project itself constitutes the remainder of this module (25 credits) and is largely self directed. It is carried out in the Autumn term (and Term 2 for Part Time students). It will provide students with the opportunity to study in depth topical aspects of Advanced Neuroimaging, making use of the extensive library, information and computer database facilities available at the Institute of Neurology and at UCL.

Learning Outcomes

Literature Search Techniques

Students will have knowledge of, and experience in using, on-line data bases for accessing current knowledge in the medical literature

Critical Review

Students will understand the need for critical review of the scientific literature, in order to assess the experimental and statistical evidence underpinning conclusions.

Written Report (Essay)

Students will know how to distill information from the scientific literature and present it in a concise, informative manner

Topical Knowledge

Students will gain in depth knowledge regarding the state-of-the art in a particular specialist area of advanced Neuroimaging

Presentation Skills

Students will learn presentation skills through workshops and through presenting their research projects to their peers and supervisors towards the end of the academic year.

Module 8: Research Project (60 credits)

Content Summary

A wide range of research topics will be offered at the beginning of the course. The project will be carried out in the Spring and Summer terms, in one of the Institute's modern research laboratories, and supervised directly by Institute research staff. The project will be written up as a full dissertation (10,000 words) and submitted before 1st August for examination by internal and visiting examiners.

Learning Outcomes

Through pursuing their chosen practical project, students will gain in depth knowledge, understanding and practical experience of their chosen research topic area, in addition to:

Knowledge and understanding of: Research and development methods appropriate to the chosen topic.

Intellectual (thinking skills) – able to: Apply theories to chosen practical examples. Critically review research literature.

Practical skills: Practical application of design and evaluation techniques. Collecting and analysing data. Reviewing literature.

Transferable skills: Argumentation and communication of ideas. Information seeking.