UCL INSTITUTE OF NEUROLOGY
QUEEN SQUARE

THE NATIONAL HOSPITAL FOR NEUROLOGY AND
NEUROSURGERY
QUEEN SQUARE
LONDON WC1N 3BG

MSc Advanced Neuroimaging – Content & Learning Outcomes

The following contains a summary of the content of each of the six taught modules:

Module P1: Scientific Basis 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 hope 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.

Module P1: Scientific Basis and Methods

Content Summary

Core mathematics
Core IT
Core Physics
Principles of image formation
Research Methodology
Introductory statistics

Learning Outcomes

Core mathematics, statistics and Research Methodology
At the end of this module, students will be able to demonstrate understanding of the basic mathematics of imaging science and statistical methods, and a knowledge of the practical skills essential for undertaking independent research.

Core IT
At the end of this module, the students will understand the basic architecture of modern computer systems, hardware and software. The students will be able to understand, design and code programs in the Matlab programming environment.

Principles of image formation
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
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,

Module P2: Imaging Modalities

Content Summary

Magnetic resonance
- Basic physics;
- Imaging pulse sequences and contrast;
- Instrumentation and safety

Computed tomography
- Instrumentation/image reconstruction
- image contrast and artefacts
- contrast agents
- CT angiography
- dosimetry/safety

Radionuclide imaging
- Basic nuclear physics
- radionuclides,
- imaging systems
- tracer/kinetic studies
- analysis, PET, SPECT

Magnetic Resonance Spectroscopy
- chemical shift, spatial localisation, data processing/ quantification, 1H MRS, 31P MRS, other nuclei, clinical applications

EEG & MEG
- Basic brain electrophysiology
- Nature of the EEG & MEG signals
- Scalp EEG & MEG measurement & instrumentation
- Display and analysis; Correlation with fMRI

Digital Subtraction Angiography
- sources, detectors, signal processing
- contrast agents, clinical procedures
- artefacts, correction strategies, safety

Ultrasound
- Soundwaves in tissue, probe operation and design
- signal processing, flow measurement,
- safety.

Learning Outcomes

Magnetic Resonance
At the end of this module the students will be able to describe the physical basis of MRI, common MRI sequences used in the clinic and for research, and demonstrate understanding of instrumentation and safety issues.

Computed Tomography
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 and dosimetry/safety

Radionuclide Imaging
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

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

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.

Digital Subtraction Angiography

At the end of this module the students will be able to describe the theoretical principles of DSA, instrumentation, dosimetry issues, and clinical applications.

Ultrasound

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

Module P3: Advanced Imaging

Content Summary

Perfusion

Bolus techniques using MR and CT
arterial spin labelling.

Diffusion

Diffusion weighted imaging; diffusion tensor imaging.
Quantitative analysis of ADC and FA. Fibre tracking

Morphometry and volumetry

Concepts; Global vs local measures;
Landmarks; Volumetry; Voxel-based methods

Data fusion and image registration

Principles and aims of multimodality imaging; Image registration; Longitudinal imaging

Imaging functional activation

fMRI contrast mechanisms; Experimental design & paradigms; Data analysis and statistics; Applications.

Special quantitative techniques in MRI

Relaxation theory, relaomerty, MT theory, MT measurement and qMT, analysis methods

Magnetic Resonance Spectroscopy

chemical shift, spatial localisation, data processing/ quantification, 1H MRS, 31P MRS, other nuclei, clinical applications

Postprocessing of vascular imaging data

MIP, surface rendering, endoluminal imaging and 3D reconstruction

Learning Outcomes

Perfusion

At the end of this module the students will understand the meaning of different haemodynamic parameters such a 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 and understanding oft arterial input function and deconvolution analysis.

Diffusion
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. The will understand the principles of diffusion tensor imaging and tractography.

MRI-based morphometry and volumetry
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.

Data fusion and image registration
At the end of this module, the students will be able to 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.

Imaging functional activation
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.

Special quantitative techniques in MRI
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.

Postprocessing of vascular imaging data
At the end of this module, the students will be able to understand the processing tools used for CTA, MRA and DSA, such as MIP, surface rendering, endoluminal imaging and 3D reconstruction.

Module C1: Introduction to Neuroanatomy, Systems and Disease

Content Summary

Introductory neuroanatomy
Physiology and Function
Anatomy and pathology of specific areas (visual pathways, brainstem)
Functional anatomy and pathology
Clinical Overview

Learning Outcomes

Neuroanatomy
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.

Physiology and function
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, functional systems

Anatomy and pathology of specific areas:

Visual Pathways
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 part of the visual pathway.

Brainstem
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

Functional anatomy and pathology

Clinical Overview
Students will be able to explain the clinical presentation of Epilepsy, Stroke, Tumours, Neurodegeneration, Peripheral Nervous System and Inflammation & Infection in terms of the disruption caused to function within the nervous system.

Module C2: Pathology & Diagnostic Imaging I

Content Summary

Tumours
Epilepsy
Stroke
Fetal Imaging
Trauma

Learning Outcomes

Stroke
At the end of this module the student will: Understand the difference between ischaemic and hemorrhagic stroke and their relative frequency; Understand the main causes of ischaemic stroke in adults and children; Identify collateral pathways in the brain; List and understand the main causes of hemorrhagic stroke including differentiating between subarachnoid and intraparenchmal haemorrhage.

The student will be able to discuss the advantages and disadvantages of MRI and CT in differentiating between ischaemic and haemorrhagic stroke. The student will be familiar with the time course of the radiological appearance of ischaemic stroke on CT and MRI with particular emphasis on diffusion weighted MRI; familiarity with ischaemic penumbra and be able to name neuroradiological technique used to define it; knowledge about the MR appearances of small vessel disease be familiar with a the most important of scoring systems aiming to quantify small vessel disease; 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; be aware of the relative sensitivity of CT and various MR sequences in detecting subarachnoid blood; be able to name causes of subarachnoid haemorrhage; have a knowledge of the sensitivity

and technical limitation of DSA, CTA and MRA in detecting cerebral aneurysms cerebral AVMs and cerebral vasospasm.

Diseases: Tumours
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; Name the most frequent intra-axial tumours; Demonstrate an understanding of the biological mechanism of glial cell tumours.

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

Epilepsy
The student will acquire knowledge of 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; surgery planning, post-op imaging

Fetal Imaging
Trauma

Module C3: Pathology & Diagnostic Imaging II

Content Summary

Neurodegeneration
Inflammationa and infections
Demyelination
Peripheral nerves and muscle disorders
Stroke / Trauma

Learning Outcomes

Neurodegeneration
At the end of this module the student will be able to: Understand 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; Will be familiar with the age of onset and long term prognosis 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.

Inflammation and infections
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); Identify factors which can cause vasculitis of the cerebral vessel (SLE, TB, drug use); Be familiar with the common neurological manifestations of AIDS and be aware of the changing pattern of Neuro-Aids with the introduction of highly active anti-retroviral therapy (HAART).

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; prion

Demyelination
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.

Peripheral nerves and muscle disorders
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.

Stroke / Trauma

Module 7: Library Project

Content Summary
This is largely self directed and will be carried out in the Autumn term. 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. It will also include taught Research Methods sessions during which students will learn practical skills essential for undertaking independent research.

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

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 once 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.