1. Introduction
Magnetic Resonance Imaging (MRI) is a highly complex scientific imaging modality that delivers exquisite anatomical and functional images of the human body. This technology requires high-level scientific and safety support for its safe and effective utilisation. This policy statement is issued by the Institute of Physics and Engineering in Medicine (IPEM) and defines the activities performed by MRI Clinical Scientists.

1.1 Scientists in MRI
Scientists specialising in MRI have first degrees in science, usually Physics, an MSc, often in Clinical Physics, vocational training and are HCPC (Health and Care Professions Council) registered [1]. An MRI Clinical Scientist requires the attainment of theoretical knowledge and practical skills which enables the individual to contribute an essential role within a multidisciplinary team that delivers an MRI service.

1.2 Magnetic Resonance Safety Expert
An MRI Clinical Scientist with a thorough and detailed understanding of MR physics, the appropriate skills, knowledge and experience of MR imaging equipment (including its uses and associated requirements) may become a Magnetic Resonance Safety Expert (MRSE). A register and national level accreditation system for MRSEs is currently being proposed [2].

2. Scientific Services in MRI
The Clinical Scientist provides development of standards of practice, the introduction and delivery of clinical services, the optimisation of pulse sequences and clinical protocols, education, research and development activities, advice and support on MRI safety, risk assessments, procurement, site design, acceptance testing and quality assurance.

2.1 Safety
MRI does not use ionising radiation, such as x-ray and radioisotope imaging techniques, and is considered much safer as a result. However, MRI poses unique, acute safety risks as a result of the use of an extremely strong static magnetic field, rapidly time-varying magnetic field gradients, radiofrequency transmission, high acoustic noise levels, and cryogenic liquids. There have been several fatalities and serious injuries related to MRI [3-10]. Many other adverse events occur in MRI, the vast majority of which are avoidable through appropriate safety training and expert support. The MRI Clinical Scientist has a crucial role in helping ensure that safety is maintained for all patients, staff and visitors and that appropriate risk assessments and standards of practice (SOPs) are in place and kept up to date with national and international guidelines and recommendations [2, 11-13].

Clinical Scientists contribute to the development of MRI local rules as well as procedural development, such as protocols for the use of MR Conditional items within the unit. Clinical Scientists maintain an up-to-date knowledge of relevant scientific, technological and regulatory developments (both national and international) and where appropriate, they recommend changes in local practice. The MRI Clinical Scientist is an integral part of the local MR safety committee. The MHRA recommends that new staff receive MR safety training and that regular updates are provided to existing staff. The MR Safety Expert typically
conduces this training. In the event of MR scanner related safety incidents, MRI Clinical Scientists are frequently involved in reviewing the specific circumstances, educating staff on the cause of an incident and implementing methods of reducing the likelihood of reoccurrence.

Patients with passive and active implantable medical devices are regularly referred for MRI. Clinical Scientists advise on the risks posed by the interaction of these devices with the extreme electromagnetic conditions associated with MRI and methods of minimising risk. In many instances, this requires the high level expertise of MRSEs, who are aware of developments in implant technology and the implications for scanning a patient using their particular MRI system. An MRSE may facilitate safe scans for many patients who would otherwise be denied MRI due to the present of contra-indicated implanted medical devices.

Safety is paramount in the delivery of an MRI service and an MRI Clinical Scientist is a critical component of this delivery.

2.2 Site Design
Installation of MRI systems may require extensive modification of existing buildings or the design of new buildings. Clinical Scientists should ideally work in conjunction with the MR manufacturer, architects, estates departments, clinical staff and PACS team to review practical considerations of the MRI suite layout to facilitate the safe and efficient throughput of patients. During the design process, a thorough knowledge of MRI and MRI safety enables the project team to ensure that certain key considerations are taken into account for the subsequent safety and management of the MRI unit and to mitigate risk as much as possible. An MRI Clinical Scientist can also advise on the mutual impact of the MRI system and the surrounding environment. National and international guidance documents recommend the inclusion of an MRSE/MRI physicist on the design team [2, 11, 12].

2.3 Quality Management
When procuring new MRI equipment, it is vital that appropriate technical performance criteria are formally specified with input from a Clinical Scientist in order to meet the diagnostic clinical service and research needs. This is essential as there is a wide range of commercially available MRI equipment and consideration must be given to intended function and required level of performance while facilitating good purchase outcomes. Procurement decisions regarding gradient specification, radio frequency coils, pulse sequences and image analysis suites should be made in conjunction with a Clinical Scientist after review of the local requirements. IPEM [2], the MHRA [11], and EFOMP [12] all recommend the designation of an MR physicist/MRSE on the procurement project team.

It is increasingly common for ancillary equipment such as power injectors, ventilators and monitoring equipment to be used within the MRI scanner room, for example to support the scanning of patients under general anaesthetic. In addition, other equipment such as that used for fMRI/EEG-fMRI (functional MRI/electroencephalogram-fMRI) requires advanced scientific support. Clinical Scientists are involved in the safety testing, procurement and labelling of appropriate ancillary equipment to support these activities, determining potential risks and developing effective management controls for their safe use.

In some instances, Clinical Scientists design and create MR Conditional equipment to be used with the MRI scanner room, ensuring it is safe and functioning properly, and does not interfere with the MRI scanner itself [14].

Assessing the functionality of important aspects of MRI scanner performance and accuracy may necessitate the purchase or design and production of dedicated test objects (phantoms) that are scanned using the MRI system. This is firmly the remit of the MRI Clinical Scientist.

2.3.1 Quality Assurance and Troubleshooting
Following the commissioning of a newly installed MRI system, acceptance testing should be performed by a Clinical Scientist, where appropriate in conjunction with the manufacturer. The acceptance test should
establish whether the software and hardware meet the procurement specification. This process also facilitates system benchmarking. The acceptance test also typically includes a site safety review and static magnetic field survey.

It is important that the images and data produced by the MRI system are accurate, reliable, and representative of the patient and of high diagnostic quality. An appropriate Quality Assurance (QA) program should be adopted to ensure that the MRI system continues to meet a standard for diagnostic use through system performance monitoring, audit, review and any necessary corrective action [11]. This is typically a role of the MRI Clinical Scientist. National and international guidance exists on how to perform acceptance testing and MRI QA [15-20].

Clinical Scientists are also regularly involved in troubleshooting artefacts and system errors and determining the root cause of scan failures and system downtime.

2.3.2 Service Delivery and Protocol Optimisation
MRI continues to see notable advances in hardware, pulse sequences, image reconstruction and image analysis. Clinical Scientists are frequently involved in the critical appraisal of new technology, implementing advanced MRI techniques into clinical practice and evaluating whether these new techniques have the potential to improve the patient care pathway.

There is an ongoing requirement to establish optimal sequences for clinical applications tailored to the anatomy and biochemistry of disease, which requires an in-depth understanding of MR physics, sequence implementation and the clinical condition under assessment. Anatomical and functional information may be missed if the wrong pulse sequence is used. MRI Clinical Scientists work with radiologists and radiographers to optimise existing techniques, for example in terms of the balance between image quality and acquisition time. Protocol changes should ideally be reviewed at departmental audit.

Image analysis can enhance and quantify the clinical information in MR images. Clinical Scientists have a role in assessing, validating, implementing and sometimes creating new analysis techniques and software.

3. Scientific Leadership
Good leadership requires the ability to think strategically, be imaginative, create a vision and achieve this vision through effective problem solving, team motivation, inspiration and management. A Consultant Clinical Scientist plays a key role in driving service improvement/development and cost reduction through service accreditation, leadership and professional interaction, by applying a balance of clinical, scientific, technical and management skills to support complex services with large multidisciplinary teams, enabling healthcare providers to deliver diagnostic and therapeutic procedures while managing risk [21]. The Higher Specialist Scientific Training (HSST), intrinsic to the Modernising Scientific Careers programme, aims to develop Consultant Clinical Scientists as experts and leaders within the Healthcare system [22]. An equivalence process overseen by the Academy for Healthcare Science enables Clinical Scientists already working at this level to achieve Consultancy status.

4. Education and Training
Clinical Scientists are extensively involved in teaching the physics of MRI and clinical applications, and delivering mandatory safety lectures to a wide range of staff groups (e.g., radiographers, radiologists, clinicians, researchers, domestic staff). It is a skilled undertaking to present such complex subject matter to an audience that may have a minimal physics/mathematics background. MRI Clinical Scientists typically deliver a lecture series to address the MRI component of the curriculum for the clinical registrars taking the First Examination for Fellowship of the Royal College of Radiologists [23]. There is frequently a need for MRI Clinical Scientists to teach across a broad range of research related topics, including as part of university
undergraduate and taught postgraduate degree programmes. Clinical Scientists often supervise postgraduate research projects at master’s and doctorate levels through University collaboration. They are extensively involved in supervising medical physics trainees [22, 24].

5. Research and Innovation
MRI is a rapidly developing field and Clinical Scientists require an understanding and awareness of cutting edge techniques and technological advances. MRI Clinical Scientists are often instrumental in driving change, translating research and development into clinical practice and implementing these techniques into routine clinical care through critical evaluation as a key member of a multidisciplinary team.

Clinical Scientists may also be involved in activities related to research, innovation and development. These pursuits require the Clinical Scientists to lead or support various aspects of the research pipeline from experimental design, protocol development, image and statistical analysis, to the presentation/publication of results. They may be principal investigators themselves; may provide vital MR physics expertise as part of a multidisciplinary team of collaborators; or may provide safety, regulatory and governance support to facilitate research performed by others.

MRI is extensively used as a research tool in clinical trials. MRI Clinical Scientist involvement is often seen as essential in these collaborative research projects through protocol optimisation, evaluation of image quality and safety on suitable phantoms, volunteers and patients, interpretation of data and audit, owing to the level of rigour and critical thinking they bring to the table.

6. Conclusion
The role of the MRI Clinical Scientist is multi-faceted and they are an essential component in the delivery of safe, modern healthcare. To quote the NHS constitution [25], regarding the NHS:

> It works at the limits of science - bringing the highest levels of human knowledge and skill to save lives and improve health.

The Clinical Scientist is a key person in the multidisciplinary field of Magnetic Resonance Imaging, often working at the limits of science, helping deliver a safe, high-quality, modern MRI service to patients.

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