Research support, innovation, and training highlights from the University Hospitals of Leicester NHS Trust Medical Physics Department in 2017 and 2018.
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Introduction

Our departmental vision is to be a strong, well recognised, value for money Medical Physics Department with a reputation for innovation and excellence with recognised benefits to patients, the Trust, research partners and external clients; and opportunities for staff.

Our staff apply their knowledge of the physical sciences and engineering to medicine, and are ideally placed to support the technical/digital revolution currently sweeping the NHS. Introduction of transformative technologies can be achieved by leading innovation in all subspecialty areas of Medical Physics, and being active in encouraging the translation and integration of Research and Innovation (R&I) activities into the wider clinical pathways of our patients.

Multidisciplinary research at UHL is central to our success. Our staff apply their knowledge of the physical sciences and engineering to a range of problems in medicine, working closely with academic partners at the University of Leicester, University of Loughborough and De Montfort University. As evidenced by this report, we have longstanding links with clinical colleagues in cardiology, vascular surgery, ophthalmology, sports medicine, diabetes, stroke, and cancer studies. We also provide an entry route to the NHS supporting translation of academic research from the University of Leicester College of Science and Engineering (physics, engineering and bioinformatics) and play a leading role in supporting medical imaging across the region.

As a department, we have been evaluating our Research and Innovation (R&I) activities since 2015 using a nationally recognised benchmarking tool. These metrics specifically recognise the breadth and depth of R&I work carried out by NHS scientific staff. Our latest figures reveal an increase in R&I activity of 66% from 2016-2017. We have a relatively young but vibrant team in Medical Physics – keen to engage with industry, and clinical and academic partners within and outside of the Trust. Several interesting projects are planned for the coming year and the outlook for the future is positive.

Highly skilled Clinical Scientists, with Masters and Doctoral level qualifications, carry out our research and innovation work, with increasing engagement from Healthcare Science Practitioners and Clinical Technologists at degree level. The Trust funds a joint post with the University of Leicester, which has resulted in an increase in UoL collaborative projects, particularly in Clinical Engineering, and provides research training and academic teaching opportunities for Medical Physics staff.
The department is active in education and training, hosting four Higher Specialist Scientists Trainees (HSSTs) and seven Scientist Training Programme (STP) trainees working across a range of Medical Physics and Clinical Engineering specialties. We also provide training for Healthcare Science Practitioners, Clinical Technologists, university undergraduate and postgraduate teaching, and training for Radiologists. The new apprenticeship scheme at Level 6 is already offering further opportunities for expanding our workforce in the coming years and is becoming increasingly important. We are extremely proud of our increase in research output and hope to build on this in coming years.

Debbie Peet

Head of Medical Physics. University Hospitals of Leicester NHS Trust
Research, Training, and Innovation in Medical Physics

BACKGROUND

Medical Physics scientific services are essential for research conducted within the UHL NHS Trust involving ionising radiation and non CE-marked medical equipment. Medical Physics staff offer specialist expertise, and lead their own research in Ultrasound physics, Magnetic Resonance Imaging (MRI), Nuclear Medicine, Radiation Safety, Radiotherapy Physics, Scientific Computing, and Physiological Measurements.

The department hosts 143 Clinical Scientists, Healthcare Science Practitioners (Technologists) and support staff working across a range of specialisms.

In brief, our mission is to:

- Perform world-leading research into the applications of Physics and Engineering to Medicine.
- Provide specialist training for the next generation of NHS Clinical Scientists, Technologists and staff.
- Lead Health Technology Assessment and Medical Physics Service Development and Innovation within the University Hospitals of Leicester NHS Trust.
- Aim to inspire the next generation of Clinical Scientists through excellence in undergraduate and postgraduate teaching.
- Provide Medical Physics and Clinical Engineering support for research conducted within the UHL NHS Trust.

This document highlights recent research projects and innovation activities led by UHL Medical Physics staff, including examples of specialist support offered for academic research, clinical trials and industry. This report also highlights our contributions to public outreach, undergraduate and postgraduate teaching, and training of NHS staff.

Particular expertise and interests include:

- Development and validation of medical devices, software, and accessories
- Technology transfer to the NHS including clinical evaluation of new therapeutic and diagnostic techniques
- Radiation Dosimetry (all ionising radiation specialisms)
- Medical radiological equipment; Safety /Quality Assurance/ Quantitative assessment
- Radiation shielding and facility design
- Simulations and Monte Carlo modelling
- Implementation of new and updated techniques (therapeutic and diagnostic)
- Audit and service evaluation
- Medical Physics education and training
PERSONAL ACHIEVEMENTS

- Georgina De Vries won the IPEM 2018 award for the best MSc project for Clinical Engineering STP trainee at King’s College London.

- Lisa Rowkey received an Institute of Physics in Engineering and Medicine (IPEM) Innovation Award to develop a dynamic cardiac phantom for Nuclear Medicine imaging applications.

- Laura Smith won the prize for ‘Best Overall Medical Physics Student’ in her MSc Clinical Sciences cohort at Newcastle University.

- New Honorary University Fellows include Dr Alex MacKenzie who became an Honorary Fellow with the University of Leicester, Department of Physics and Astronomy and Dr Edward Pallet who became an Honorary Fellow within the University of Leicester, Department of Cardiovascular Sciences.

- Dr Alex MacKenzie (Radiation Safety), Georgina De Vries (Clinical Engineering), and Laura Smith (Radiotherapy) successfully completed their STP training to become qualified Clinical Scientists. Dr Caroline Banahan, Dr Emma Chung, Richard Farley and Dr Evangelia Kaza successfully achieved Clinical Scientist registration following the Association of Clinical Scientist (ACS) equivalence route.

- Dr Caroline Banahan qualified as a Laser Protection Advisor (LPA).

- In March 2018, Medical physics staff took part in British Science and Brain Awareness week; their ‘pulsing brain’ exhibit at Creat-A-Con, attracted over 600 visitors.

- Dr Emma Chung became a Fellow of the Institute of Physics (FInstP) and Fellow of the Higher Education Academy (FHEA), and joined the committee of the Midlands Medical Imaging Network.

- Poppy Turner (PhD student) won the IPEM best poster prize for her poster: ‘Development of an ultrasound phantom for investigating brain tissue pulsations generated by the major cerebral arteries’ at the Medical Physics and Engineering Conference (MPEC), 13th-14th September, Sandown Park, Surrey.

- Georgina De Vries joined the IPEM Trainee Panel

- Jasdip Mangat was secretary of the IPEM Engineering Advisory Committee and professional lead for Clinical Engineering for the Academy of Healthcare Science, working as an assessor for the
Debbie Peet was Clinical Lead for development of a British Institute of Radiology e-learning for healthcare (e-IfH) module aimed at vascular surgeons.

Debbie Peet was Chair of the Radiation Protection Special Interest Group for IPEM—a challenging role covering new guidance for working with ionizing radiation, patient safety, and Environmental Protection.

Debbie Peet is Lead Healthcare Scientist for the UHL, which involves representing scientific staff across the Trust.

For International Day of Medical Physics in November 2017, female Medical Physics staff contributed to an IPEM poster to mark the 150th birthday of Marie Curie.

Carl Bond represented University Hospitals of Leicester on the National Performance Advisory Group (NPAG) Clinical Engineering group.

In 2018, Jasdip Mangat and Emma Chung launched a leaflet advertising Medical Physics and Clinical Engineering Scientific Support (CESS) at the Leicester Business Festival.

Jasdip Mangat contributed to a UK presentation for Global Clinic Engineering day on 21st October 2017—How to become a Clinical Engineer in the UK.
Clinical Engineering

Clinical Engineering facilities include dedicated electronics and mechanical workshops for the design and development of bespoke electronic devices, electrical safety testing, and facilities and expertise for the evaluation and repair of medical devices. Many of our staff are active researchers with doctorates in Medical Physics or Engineering, and are able to provide expert advice and support regarding the development and implementation of novel technologies and software within the NHS. Our team works closely with research colleagues across the Trust and the University of Leicester to maintain essential safety requirements and assist in the translation of research to a clinical environment.

DEVELOPMENT OF A DEVICE FOR TREATING INTESTINAL INTUSSUSCEPTION IN INFANTS

Intestinal intussusception is the most common abdominal emergency affecting children under 2 years old. It occurs when one portion of the bowel slides into the next, causing the bowel to become obstructed. The UHL mechanical workshop have developed a medical device for safe inflation of the infant bowel to help avoid the need for surgery. This intussusception device produces a small, controlled, increase in pressure to gently inflate the bowel and relieve the blockage. This device, originally developed by Clinical Engineering for ‘in house’ use approximately 20 years ago, required updating. Clinical Engineering compiled new user requirements to inform the device specifications, and completely reviewed the device design to incorporate additional safety features.

The resulting intussusception device comprises two pressure valves: a pressure control valve to inflate the bowel according to the clinical protocol and a pressure relief valve ensuring that pressure never exceeds a maximum limit. A customised pressure gauge was developed, so that clinicians can easily monitor the administered gas. All components are compatible with 100% O₂ and the system has undergone comprehensive verification and validation testing. We are currently investigating options for IP protection and CE-marking to allow our intussusception device to be used by other hospitals.
NEONATAL TRANSPORT TROLLEY MODIFICATIONS

There are currently four neonatal transport trolleys in use; two based at Nottingham University Hospitals (NUH) and two at UHL. Trolleys are equipped with vital life-support systems, allowing safe transport of critically ill babies between hospitals. In this work, for the CenTre neonatal transport team, we performed modifications to existing transport trolleys, replacing their current portable suction device with a smaller, transport-rated, device, and adding a high-flow oxygen blender. We performed an options appraisal and risk assessment to take into consideration factors such as weight, usability, risk, cost, and time constraints. The Clinical Engineering team developed a manifold system to connect the air and oxygen supply, interchangeably, to the ventilator and oxygen blender. The system received positive feedback has now been in clinical use for several months.

PAEDIATRIC TRANSPORT TROLLEY MODIFICATIONS

The paediatric transport service for the East Midlands (COMET) transfers critically ill children between hospitals. These transport trolleys require a range of specialist medical equipment, such as ventilators and monitors, with power requirements that are not always compatible with the power capabilities of different ambulances. For reliable delivery of power to all devices, the Clinical Engineering team conducted a risk assessment investigating the power requirements of devices on the trolley, and the power capabilities of different ambulances (from the ambulance’s 12 V supply). This showed that the trolleys needed reconfiguring to take additional interchangeable equipment and include a power inverter. As part of our improvements, we secured the vital signs monitor in such a way that it was able to rotate, enabling visibility of vital signs at all stages during transport. Finally, the team worked with clinical staff to develop a new user manual to aid training. These modifications have improved the care of critically ill children during transport, ensuring that our regional transport trolleys are compatible with all types of ambulance.
ACCESSORY FOR THE ARTIFICIAL PANCREAS SYSTEM

A team of researchers from the University of Cambridge, Diabetes Modelling group, led by Dr. Roman Hovorka, have developed and clinically tested an artificial pancreas system. The core components of this artificial pancreas comprise a subcutaneous glucose monitor (CGM), a control algorithm, and an insulin pump. In the most recent generation of the artificial pancreas, the control algorithm and main platform software, which communicates with the CGM and insulin pump, resides as an ‘App’ on a mobile phone, which connects to a small Bluetooth dongle that communicates with the devices.

Development of a phone enclosure for Artificial Pancreas research.

UHL clinical Engineering have been supporting this high profile research team by developing a custom enclosure assembly for housing the mobile phone, Bluetooth dongle, and a mini-USB connection cable. The enclosure is required to be as thin as possible to ensure the phone can be charged via an inductive phone charger, and small enough to ensure the final assembly can fit into the users’ pockets. The enclosure components were modelled using a CAD package and prototypes 3D printed using the Trust’s 3D printer. The final design is mass-produced via injection moulding. UHL Clinical Engineering are responsible for assembling the systems and supplying the University of Cambridge for multi-centre studies conducted worldwide.
IMAGE SEGMENTATION FOR ARTIFICIAL ORGAN DESIGN

Members of UHL Clinical Engineering supported an Open University research project, funded by the Engineering and Physical Sciences Research Council (EPSRC), which has succeeded in developing software for the design of artificial arterial trees. These computer-generated arterial trees reveal the optimal arrangement of arteries required to supply a given tissue geometry and metabolic demand determined from an MRI scan. An example of an artificially generated vasculature to supply the white and grey matter of the brain, and predicted perfusion territories of the major arteries, are shown below. We are currently exploring whether this software might be useful for medical diagnostics or artificial organ design.

Grey and white matter segmented from an MR image (left) and artificially generated vascular trees (centre). Predicted perfusion territories of the major arteries in the artificial vasculature (right) are similar to those of the real brain.

BRAIN TISSUE VELOCIMETRY (BRAIN TV)

Brain TV is a prototype physiological measurement system developed in partnership with Nihon Kohden, Japan, for non-invasive emergency diagnosis and monitoring of brain injury. Clinical Engineering have been working closely with Nihon Kohden, and researchers from the University of Leicester, to test Brain TV in healthy volunteers and obtain regulatory (HRA and MHRA) approvals for further investigation of Brain TV in clinical trials.

Brain TV prototype (left), MRI showing the path of the ultrasound beam (centre) and brain tissue motion as a function of depth (right).
Leicester Radiation Safety Services (LRSS)

Leicester Radiation Safety Services offers advice to researchers, the emergency services, local business, and other Health Practices on all aspects of radiation safety. LRSS helps to ensure that the uses of X-rays and other sources of radiation, ultrasound, MRI, light (UV), and lasers comply with recommended guidelines and legislation. LRSS is also responsible for assessing the radiation dose associated with clinical trials as part of processes for gaining NHS ethical approval. The LRSS team includes nationally recognised Radiation Protection Advisors (RPAs), Mrs Debbie Peet and Mrs Elizabeth Davies.

Key interests within the section include:

- Radiation safety culture
- Justification processes for exposure of patients to medical radiation
- Image quality and image processing
- Translation of innovations in all areas of medical diagnosis and treatment to the NHS

LRSS covers all safety and quality assurance (QA) aspects of diagnostic imaging using both ionising radiation (X-rays and Nuclear Medicine) and non-ionising techniques such as ultrasound, MRI, Lasers, and light therapy. In addition to providing support for local clients and clinical services within UHL, many of our staff have a background in research, and are able to support the development of imaging phantoms, introduction of new services to the NHS, and scientific collaboration for funded academic research.

In addition to services provided to the Trust, LRSS delivers teaching and learning to medical and nursing staff and local universities. These include a nationally recognised Fellow of the Royal College of Radiologists revision course and a UK course on the practical treatment of Chronic Total Occlusion within cardiac catheter labs. In 2017-18, LRSS also supported an external company in providing a cadaver course within a local university.

The Radiation Safety team help to ensure that uses of radiation comply with recommended guidelines and legislation for the use of X-rays and other sources of radiation, ultrasound, MR, light, and lasers. We are also responsible for assessing the radiation dose associated with clinical trials as part of processes for gaining NHS ethical approval. Applications supported by LRSS in 2017 and 2018 are summarised below.

<table>
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<th>Year</th>
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<th>Number</th>
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<tr>
<td></td>
<td>Local compliance with IRAS</td>
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</tr>
<tr>
<td>2018</td>
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<td>16</td>
</tr>
<tr>
<td></td>
<td>Local compliance with IRAS</td>
<td>33</td>
</tr>
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*Research Governance support provided for research studies within the UHL NHS Trust.*
LRSS supports the development of NHS staff through a number of training routes, from technicians transferring to Clinical Scientist training, to Clinical Scientist accreditation through equivalence. We also support traditional routes into Medical Physics, including the NHS Scientist Training Programme and Higher Specialist Scientist Training (HSST) schemes. In 2018, one of our trainees presented at the annual national conference for Radiation Protection Advisers on a project measuring the Radiation Safety Culture within different areas of the Trust to identify potential areas for improvement. This trainee will also undertake an MSc project in 2019.

In 2017-18, the Head of Leicester Radiation Safety Services, Mrs Elizabeth Davies, helped to update the contingency planning chapter of the UK Medical and Dental Guidance notes, which resulted in her giving an invited talk to the Association of University Radiation Protection Officers annual conference in 2018 on the topic of contingency planning and co-operation between universities and hospitals. Mrs Davies has also initiated a three-year doctoral level research project, as part of her Higher Specialist Scientist Training, into justifications for radiation exposures using Markov modelling.

**LRSS WELCOMES ‘JEREMY’ TO THE TEAM**

Recent purchase of an anthropomorphic Kyoto phantom, locally named Jeremy, has opened new opportunities for optimisation projects. So far, Jeremy has been used in Radiotherapy, Nuclear Medicine, and Imaging to provide an indication of clinical image quality using different protocols. He is also useful for training purposes and in demonstrating the support LRSS provide to the Trust in public open days.

Image of ‘Jeremy’ being scanned at Leicester, courtesy of RAD magazine.

Over the next year, we aim to develop expertise in image processing within LRSS towards the development of quantitative quality control measures. A member of our staff is working with a radiologist to produce a paper on Kidney, Ureter and Bladder (KUB) doses over time, which we hope will strengthen our academic links with Radiology. LRSS also support the implementation of new imaging protocols through various medical exposures committees and Quality Control tests using a variety of phantoms for assessing image quality. We are also heavily involved in training throughout the Trust and at De Montfort University.
SHEAR WAVE ELASTOGRAPHY ULTRASOUND PHANTOM

Ultrasound Shear Wave Elastography (SWE) measures the elasticity of tissue (Young’s Modulus) by using ultrafast ultrasound imaging to map the speed of propagation of ultrasonic shear-waves. Our centre was one of the first to investigate possible vascular applications. Currently our team is developing an Elastography Phantom for assessing the accuracy of shear wave elastography in estimating tissue elasticity with decreasing target diameter.

BRAIN TISSUE VELOCIMETRY PHANTOM

Members of LRSS have also led the development of an anthropomorphic brain phantom to mimic brain tissue motion. This phantom involves printing a 3D-printed skull based on CT data. The 3D-printed skull is used to house a silicon vascular replica and filled with a soft PVA-based tissue mimicking material to mimic brain tissue. To test the suitability of the 3D printed material as a substitute for bone, beam plots were obtained using the Leicester beam plotting facility for comparing the acoustic properties of the 3D printed material with that of real skull.

Anthropomorphic brain tissue-motion phantom for MRI and ultrasound applications.
MR IMAGING OF CEREBRAL MICROBLEEDS FOLLOWING CARDIAC SURGERY

This British Heart Foundation study led by Dr Emma Chung, in collaboration with Xinapse Ltd. and St George’s Hospital in London used MRI to map the distribution of pre-existing and new cerebral microbleeds found in patients’ brains following cardiac surgery. As part of this study, ‘before and after’ MR susceptibility-weighted images were compared using a digital subtraction algorithm. Cerebral microbleeds were found to be related to the duration of cardiopulmonary bypass and low blood haematocrit levels. Having identified the potential causes of these injuries, we hope it will be possible to reduce cerebral microbleeds in patients undergoing heart surgery in the future. This research was published in the international journal, Stroke.

New cerebral micro-bleeds in patients following cardiac surgery detected using MRI.
Radiotherapy Physics

The radiotherapy department at Leicester Royal Infirmary treats approximately 2200 cancer patients each year, delivering approximately 32,000 fractions of treatment using four state-of-the-art linear accelerators (linacs). The Radiotherapy Physics section provides the scientific and technical basis for radiotherapy treatments and includes Clinical Scientists and Clinical Technologists (working in treatment planning and linac engineering). Scientists play a significant role in the development and safe introduction of new techniques and equipment: commissioning and testing treatment machines and planning and dosimetry systems to ensure patients are treated safely and effectively.

The department supports cancer research as part of several large multi-centre studies conducted by the University of Leicester. Radiotherapy physics staff involved in R&I include Clinical Scientists, Higher Specialist Scientist Trainees, Clinical Technologists and a dedicated Research Physicist. Multidisciplinary team working with Radiographers and Consultant Clinical Oncologists is essential to service delivery and innovation.

RECTUM AND ANUS INTENSITY MODULATED RADIATION THERAPY (IMRT)

Rectal and anal cancer patients currently receive conventional 3D conformal radiotherapy treatment, which we are in the process of replacing with Intensity Modulated Radiation Therapy (IMRT). IMRT enables treatment of tumours using higher dose levels, whilst reducing the dose to nearby organs at risk, such as the bowel. This can help to minimise unpleasant side effects of radiotherapy treatment by reducing damage to nearby organs.

Research Physicist, Mrs Klaudia Krzekotowska, recently presented a poster entitled ‘Improving late toxicity following curative treatment for cervical cancer’ at the UHL Consultants Conference in September 2018.

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**Improving late toxicity following curative treatment for cervical cancer**

**Background**

Standard treatment for inoperable rectal cancer is chemoradiotherapy followed by surgery. Intensity-modulated radiotherapy (IMRT) is used to treat patients using conformal radiotherapy to the treatment area whilst minimising unwanted dose to nearby normal tissue. IMRT requires a planning CT scan with contrast that is used in conjunction with the imaging scan to outline the treatment area (tumour, normal tissue). From this plan, the dose arrangement of radiotherapy beams can be planned to accurately deliver the radiotherapy. Modifying the normal tissue reduces long-term toxicity. A 3D conformal plan can be produced to use as a backup option.

A number of patients were noted to be unable to maintain optimal bladder filling throughout the six-week course of radiotherapy treatment, and consequently the IMRT plan could not be used. As a result, the 3D conformal back-up plans had to be used resulting in higher fields, higher doses of radiotherapy delivered to normal tissues and subsequent increased late toxicity. The reason for this was investigated further.

**Methodology**

(1) 80 patients receiving chemoradiotherapy for cervical cancer over a 5-year period between January 2014 and January 2019 were identified.
(2) Individual bladder volumes were determined on the planning CT scan by outlining the bladder on every slice and calculating the gross volume.
(3) 2D images of the bladder in 1 slice were also measured, as this is quicker and a more realistic surrogate that may be implemented clinically.
(4) Patients requiring use of the 3D conformal back-up plans for more than 30% of their daily 5-week treatment (following 3-week interval) are highlighted.

**Background**

- 80 patients were identified with a median age of 46 years (range 21-88 years)
- The combined treatment was chemoradiotherapy for the cervix (52%), adenocarcinomas (18%) and 1 patient had a large cell carcinoma of the cervix (24%)
- The majority of patients were T3/T4, stage III/IV
- The bladder volume at planning CT for patients requiring the use of the 3D conformal back-up plan for more than 30% of treatments was compared to the bladder volume for those able to proceed with IMRT.
- The mean bladder volume was higher in patients who needed to use the back-up plan compared to those who did not.

**Conclusion**

Patients with a bladder volume that is either too small or too large at an initial CT scan will not be able to replicate this throughout treatment, requiring them to use the back-up 3D conformal plan, resulting in increased toxicity to normal tissues.

**Future recommendations**

- At the time of planning CT, a patient with a bladder volume > 500 ml results the scan repeating prior to radiotherapy planning to ensure reproducibility.
- There is current research correlating bladder volume from an ultrasound bladder scan to those from a planning CT scan. This has the advantage of using non-ionising radiation, adhering to the ALARA principle. Applying this technique to radiotherapy planning will reduce unnecessary exposure to radiation and decreasing the late effects using the IMRT plans, resulting in optimal cancer control without increasing late toxicity.

This is an area of very interesting research which should be further investigated.

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NEW ‘VARIAN TRUEBEAM’ LINAC
Leicester’s Hospitals was one of the first centres in England to benefit from a national £130m investment programme to upgrade radiotherapy treatment machines. Funded by NHS England as part of the largest radiotherapy upgrade programme in 15 years, the new TrueBeam Linear Accelerator (Linac) offers state of the art capabilities to allow the team at Leicester’s Hospitals to deliver the best possible care for cancer patients. This includes On Board Imaging (OBI), respiratory gating, RapidArc delivery, a 6 degrees of freedom couch, and Flattening Filter Free (FFF) treatment delivery. Radiotherapy Physics staff commissioned this into clinical use in 2017, and it has been treating patients since May 2017.

ARIA ONCOLOGY MANAGEMENT SYSTEM UPGRADED
In July 2017, the Oncology Management System (OMS) received a major software and hardware upgrade, which required extensive testing and commissioning. As a result, additional functionality is now available, safety has improved, and treatment planning calculations are much faster. New algorithms are also available to improve accuracy in complex cases.
DEEP INSPIRATION BREATH HOLD (DIBH)

Radiotherapy to the left breast is sometimes associated with an increased long-term risk of heart disease due to inclusion of heart tissue in the treated volume. DIBH is a technique where the patient holds their breath for up to 20 seconds while X-ray treatment is delivered. This moves the heart out of the treatment field, which reduces radiation dose to the heart to prevent harmful side effects.

DIBH at Leicester uses a novel respiratory gating system comprising a reflective marker-block, placed on the patient’s chest, and an infrared tracking camera to measure respiration, displayed as a waveform. Gating thresholds are set so that the treatment beam switches on only when the tumour is in the right position in the respiratory cycle. A tablet PC provides a visual cue to help patients control their breathing. The blue box shows the desired threshold window, set individually for each patient; the green line moves up and down as the patient breathes. The respiratory gating system can be used for DIBH patients and to enable 4D CT acquisition for lung treatment planning.

NEW RADIOTHERAPY CT SCANNER

A second Canon Aquilion Large Bore CT scanner was installed in the department in May 2018. CT scans are essential for planning radiotherapy treatment and a second scanner provides additional capacity and service resilience. This scanner incorporates latest advances in reconstruction technology (Adaptive Iterative Dose Reduction 3D) which reduces dose to the patient and improves image contrast, and metal artefact reduction (SEMAR), which improves image quality of soft tissue adjacent to metallic implants such as artificial hips.
STEREOTACTIC ABLATIVE RADIOTHERAPY (SABR)

SABR is an advanced treatment technique that delivers a very high dose over a smaller number of treatments than conventional radiotherapy. This technique was first used at UHL in 2014 to treat lung tumours and the 100th SABR patient was treated in May 2017. UHL was successful in being one of 17 centres chosen to deliver SABR for oligometastatic sites, such as the spine, as part of the NHS ‘Commissioning through Evaluation’ scheme.

Due to the steep dose gradients of SABR, high-resolution film is required to verify treatment accuracy. This project therefore required commissioning a film scanner and developing a patient-specific Quality Assurance programme using GafChromatic film. Radiotherapy Physicist, Anna Mason, presented an ‘Audit of set-up accuracy for SABR oligo-metastases’ in November 2018 at the UK SABR Consortium meeting.

The SABR team
Support for NIHR portfolio studies and Clinical trials

**COMPARE** - Phase III randomised controlled trial Comparing Alternative Regimens for escalating treatment of intermediate and high-risk oropharyngeal cancer

**NIMRAD** - A randomised placebo-controlled trial of synchronous NIMorazole versus RADiotherapy alone in patients with locally advanced head and neck squamous cell carcinoma not suitable for synchronous chemotherapy or cetuximab

**DeESCALaTe** - Determination of Epidermal growth factor receptor inhibitor (cetuximab) versus Standard Chemotherapy (cisplatin) early and late toxicity events in human papilloma virus positive oropharyngeal squamous cell carcinoma.


**Fast Forward** - Randomised clinical trial testing a 1-week course of curative whole breast radiotherapy against a standard 3-week schedule in terms of local cancer control and late adverse effects in patients with early breast cancer.

**Requite** – Validating predictive models and biomarkers of radiotherapy toxicity to reduce side-effects and improve quality-of-life in cancer survivors

**PACE** - International randomised study of prostatectomy vs stereotactic body radiotherapy (SBRT) and conventional radiotherapy vs SBRT for early stage organ-confined prostate cancer

**POSNOC** – adjuvant therapy alone versus adjuvant therapy plus clearance or axillary radiotherapy. A randomised controlled trial of axillary treatment in women with early stage breast cancer who have metastases in one or two sentinel nodes.
ULTRASOUND BLADDER SCANNER STUDY

Variations in bladder volume during pelvic radiotherapy treatment can lead to uncomfortable genitourinary and gastrointestinal side effects. Ultrasound bladder scanning has been proposed in the literature to improve reproducibility between planning and treatment.

The aim of this study was to provide a quantitative basis for incorporating a CUBEscan Biocon-700 ultrasound bladder into local practice. We found that ultrasound bladder scanning is feasible to implement into radiotherapy workflows and may help to minimise radiation dose to organs at risk. This small cohort study suggests that a pragmatic drinking protocol aimed at achieving a minimum ultrasound bladder volume of 200 ml at planning would be beneficial. The measured ultrasound volume prior to treatment should be at least 50% of that measured at planning. Our STP student, Laura Smith, led this study for her MSc project, supervised by Dr John Gittins, Dr Kumar Ramnarine, and Dr Emma Chung.
Electrodiagnostic Services (EDS)

Electrodiagnostic Services (EDS) offers research support to clinical departments within the University Hospitals of Leicester and the University of Leicester, and contributes to ongoing research projects investigating fundamental mechanisms underlying sight, hearing and balance. We currently have a number of service development projects underway, including the commissioning of new items of patient test equipment and new patient tests.

Newborn hearing screening manager, Donna Riley, is involved with Public Health England as a peer reviewer and as an examiner for hearing screeners taking the Observed Structured Clinical Examination part of their Newborn Hearing Screening Programme training.

EDS is actively involved in the support and development of trainees; this includes EDS trainees and Medical Physics STP’s. Clinicians and other NHS staff occasionally attend/shadow our clinics to inform their referrals and improve their understanding of our tests. For example, one doctor attended weekly over a number of months to help him to implement the tests at his own hospital.

EDS staff are encouraged to attend and present at national and international conferences. Over the past 2 years, our staff have presented 3 posters; 2 at the British Society of Audiology (BSA) 2017 conference, and 1 at the International Society for Clinical Electrophysiology of Vision (ISCEV) 2018 conference. Our staff also gave an oral presentation at the British Society for Electrophysiology of Vision (BrisCEV) 2017 conference, a clinical case study at ISCEV 2018, and co-chaired a new peer review session at BrisCEV 2018. One of our staff, Ms. Jessica Adamson received a travel grant to attend ISCEV 2018 in Reims, France.

EDS staff regularly attend and contribute to Ophthalmology multidisciplinary team meetings both to discuss case studies involving electrodiagnostic tests (EDTs) and to deliver training to referrers on the tests that we offer. EDS are also represented at Audiology Interest Group (PAIG) meetings, the Newborn Hearing Screening Programme Clinical Governance and Quality Improvement (NHSPCGQI) meeting, and the Ear Nose and Throat (ENT) Divisional meeting. EDS audiologists participate in a regional (Midlands) peer review group where waveforms are reviewed by an external colleagues to check for inconsistencies, and interesting cases are reviewed and discussed. Two audiologists within EDS are accredited peer reviewers in this program, so are involved in reviewing waveforms submitted by other sites.

Jessica Adamson presenting her poster at ISCEV 2018.
EXTERNAL FUNDING SUCCESSES

Over the last two years, we have been successful in our bids for charitable funds for a new electric reclining patient chair to improve patient experience during our Audiological tests, and a new trolley for secure transport of equipment when testing patients in wards and theatres. EDS also received a large sum of money to refurbish an unused room into a new visual test studio and to refurbish existing EDS facilities to enhance patient and staff experience.

OPHTHALMOLOGY RESEARCH SUPPORT

For several years, EDS has been involved in collaborative research with the Ophthalmology Research Group, led by Professor Irene Gottlob. The research team of Professor Gottlob specialises in the study of patients with congenital Nystagmus, investigating aspects of genetics, epidemiology, and drug treatment. Our input to this work has been to provide electrodiagnostic testing of patients to help determine if their nystagmus has resulted from a visual abnormality (of the retina or nerve) at birth; from the presence of Albinism, Ocular Albinism or Achiasmia; or is of unknown origin. We are also involved in a study of a group of albinism carriers to aid in the detection of retinal changes. EDS is currently assisting ophthalmology with an ongoing clinical trial for Cancer Research UK to test for retinal toxicity in patients undergoing a novel drug therapy.

NEWBORN HEARING SCREENING PROGRAMME (NHSP)

NHSP sits within the Department of Medical Physics, but is managed separately from EDS. Close co-operation is required between the two sections to ensure the best care is received by patients. Evidence of our success was confirmed by an audit, published by Public Health England (December 17), titled ‘Time from screening outcome to attendance at an Audiological appointment (NH2 Standard 5): learning from best performing sites’. Auditors asked 18 of the best performing NHSP sites to participate in a survey to ascertain factors that enabled them to achieve their targets; Leicester’s ongoing high performance, the second best performing site in the country despite having one of the highest number of births, resulted in us being selected to be one of these 18 sites.

Clinical audits in EDS and NHSP contributed to Medical Physics receiving the runner-up award for Clinical Audit Specialty of the Year.
Nuclear Medicine

Research opportunities in Nuclear Medicine have increased with the introduction of Single Photon Emission Computed Tomography (SPECT) – X-ray Computed Tomography CT hybrid imaging at LRI and Glenfield, a fixed PET/CT scanner operated by Alliance Medical Ltd, and the appointment of new consultant and trainee radiologists specialising in Molecular Imaging. New tests and therapies at UHL are in place, or being planned, as a result of the multidisciplinary work that is now possible, including Cardiac PET/CT. A newly appointed Clinical Scientist has also become an Honorary Fellow with the University of Leicester, Department of Physics and Astronomy. In 2018, the Nuclear Medicine organised a regional meeting at the National Space Centre to highlight some of this work.

State of the art SPECT CT system

The service conducts some 7000 investigations and treatments per year across UHL. We additionally provide support to commercial and non-commercial research trials within the Trust. At any given time there are typically 20 or more research trials involving Nuclear Medicine across UHL. The level of support for each trial varies widely; some trials require significant input and expertise from our radiopharmacy, Clinical Scientists, technical, nursing and other staff groups in Nuclear Medicine.

The isotope laboratory and licensed Radiopharmacy facilities at Leicester Royal Infirmary provide support for trials involving complex radiopharmaceutical manipulation, and a wide range of isotopes and novel techniques for research. Technical, nursing, and other members of staff, manufacture and administer radiopharmaceuticals, perform diagnostic imaging and non-imaging procedures, image processing and data capture for trials, and assist with therapeutic procedures.
Clinical Scientists in Nuclear Medicine support the above aspects of service delivery and ensure appropriate research governance for the Nuclear Medicine aspects of each trial. This includes the provision of expert advice to ensure the safety of patients, staff, and the public, and to support researchers in navigating the broad array of legislation that impacts research involving radioactive materials.

Senior Nuclear Medicine scientists are Medical Physics Experts (MPEs) as defined in the Ionising Radiations (Medical Exposures) Regulations 2000. Nuclear Medicine MPEs are responsible for assessing radiation risks to trial participants and preparing applications for NHS ethical approval (IRAS and ARSAC applications) for all research involving administration of radioactive materials.

2017-2018 saw:

- 17 ARSAC research certificates applied for and obtained
- The switch to a new ARSAC system so that all standard investigations can be performed under research following a central trial approval
- Over 50 research nuclear medicine studies conducted.

**CLINICAL TRIALS**

Clinical trials supported by Nuclear Medicine staff include HARP III (investigating a new treatment for chronic kidney disease), Euro-Ewing (a large multi-centre trial investigating Ewing’s sarcoma and related tumours) and many others.
Outreach

Outreach activities include open days, public and patient involvement (PPI), Stalls and Science Fairs, and visits to local schools. We regularly participate in National Science week and National Healthcare Science Week. Examples of recent activities include:

ELECTRODIAGNOSTICS ENGAGEMENT INITIATIVES

Staff members within EDS produced a poster to describe the tests that they perform in lay terms; this is on display in our patient waiting area.

A second poster, aimed at clinical staff, has been designed to describe the visual tests that they do; this is displayed in the Orthoptics staff room and copies have been distributed to staff.

EDS also works closely with referrers to refine their referral forms to make it clear which tests are required to answer different clinical queries, thus streamlining the referral process and ensuring the patient gets the most appropriate tests in a single visit. Several members of the EDS team attended an Annual Public Meeting in Sept 2017 to raise awareness of the work of this valuable service.

Healthcare Science week, March 2017

Derek Howie and Laura Smith supported Healthcare Science Week at UHL in March 2017.

They provided a laptop simulation for staff and the public to try their hand at treatment planning, and demonstrated the masks produced to immobilise patients during cancer treatment.

Radiotherapy equipment, such as flattening filters and multi-leaf collimators, were also displayed.
BRAIN AWARENESS DAY, MARCH 2018

The ‘pulsing brain’ was an interactive exhibit held at the Leicester Creative Business (LCB) Depot as part of ‘Creat_A_Con’ for British Science week and Brain Awareness week in 2018. The event attracted over 600 visitors from in and around Leicester.

Our exhibit included paper ‘brain hats’ for children to make, child-friendly 'hands-on' ultrasound scanning, a demonstration showing ultrasound measurement of brain blood flow, and a pulsing (occasionally exploding!) brain phantom. We received extremely positive feedback from teachers and the public.

Selected images from the ‘pulsing brain’ exhibit for British Science week. The exhibition included a TMM phantom for people to scan, a pulsing brain phantom, and paper ‘brain hats’ for children to make.
IMAGING OPEN DAY 2017 AND 2018
Radiation Safety provided stalls for the UHL NHS Trust Imaging Open day 2017 and 2018 covering the basics of Radiation Safety, monitoring devices, and Quality Control tests.

BIG BANG FAIR
Medical Physics regularly supports the Big Bang Fair by attending the IPEM stall.

INTERNATIONAL DAY OF MEDICAL PHYSICS, NOVEMBER 2017
This Institute of Physics in Engineering and Medicine (IPEM) initiative celebrated women in Medical Physics by showed images of 150 women medical physicists to mark the 150th birthday of Marie Curie.
Medical Physics seminars

The Department organises a lively and well-attended seminar series, providing an opportunity for all staff to learn more about Medical Physics.

**Dinosaur Radiography at UHL**

Mostly X-ray people, but occasionally dinosaurs. Come and see some of the X-Ray images of dinosaurs produced at UHL; find out why we X-ray dinosaurs and what the images tell us. Warning — People who are offended by the idea of evolution should stay away.

For more information, contact Colin Ross by e-mail at colin.ross@uhl-tr.nhs.uk

**Proton Therapy in Switzerland—An STP Elective**

Proton therapy is here in the UK! There’s been a lot of attention around the use of proton therapy in the UK but other countries have been there and done that. One of these places is the Paul Scherrer Institut (PSI) in Switzerland, using protons to treat since 1984. Please join me to find out more.

For more information, contact Sunny Patel on 0116 258 5996 or sunny.patel@uhl-tr.nhs.uk

**MEDICAL PHYSICS SEMINARS 2017**

- **Optical Computed Tomography.** 10th January 2017: Frank Proudlock and Viral Sheth
- **Passive RF ID tagging** 15th February 2017: Steve Hunt
- **Scientific computing** 15th March 2017: Steve Hunt
- **Diagnosing brain injury using Doppler ultrasound.** 26th April 2017: Emma Chung
- **CT Dose optimization, an initial project review,** 24th May 2017: Richard Farley
- **Modernising the approach to radiation dose audits.** 14th June 2017: Georgina de Vries
- **STP Elective: Film dosimetry for the MR-Linac.** 21st June 2017: Laura Smith
- **SABR for oligometastatic disease.** 22nd June 2016: Ania Morenc
- **IT networks and medical devices; implementing ISO 80001.** 2nd August 2017: Georgina de Vries
• **Deep Inspiration Breath Hold for Radiotherapy to the left breast.** 26th October 2016: Anna Mason
• **Learning from Radiotherapy Errors.** 22nd November 2017: Andrea Wynn-Jones
• **Sports injury clinic.** 29th November 2017: Michael Withers
• **The artificial pancreas system.** 6th December 2017: Roman Hovorka (University of Cambridge)

**MEDICAL PHYSICS SEMINARS 2018**

• **Investigating the effects of blood pressure on brain tissue pulsations.** 28th March 2017: Georgina De Vries
• **EDS – the Service.** 18th April: Joanne Cowe
• **Study of ultrasound bladder scanning in pelvic radiotherapy.** 16th May 2017: Laura
• **The Research Design Service - RDS.** 30th of May: Rachel Evley
• **Dinosaur Radiography at UHL.** 13th of June: Colin Ross
• **Van Der Graaf Generator – a Blast from the Past.** 18th July: Steve Hunt
• **Proton therapy in Switzerland – an STP elective.** 10th October: Sunny Patel
• **Placement in Clinical Engineering.** 17th October: Saidi Rashid
• **Equivalence through the AHCS.** 24th October: Jasdi Mangat
• **Changes to the measurement of kidney function in Nuclear Medicine.** 5th December: Alex Mackenzie
Training

The Medical Physics Department co-ordinates a comprehensive teaching programme to address the needs of our internal trainees, University of Leicester and De Montfort University students, and staff development of Clinicians and Scientists within the University Hospitals of Leicester NHS Trust. Medical Physics also support the Modernising Scientific Careers (MSC) training scheme for Healthcare Scientists, hosting two Scientist Training Programme (STP) posts per year, two Practitioner Training Programme (PTP) Graduate Diploma posts per year, as well as supporting Higher Specialist Scientific Training (HSST) for selected NHS staff. Clinical Engineering currently have ten staff members undertaking relevant apprenticeship programmes from level 2 to level 6. We encourage professional development activities of the Institute of Physics and Engineering in Medicine (IPEM), the Institute of Engineering and Technology (IET), Institute of Physics (IoP) and relevant medical societies, such as the Royal College of Radiologists (RCR). Both UHL and University staff hold prominent positions within relevant networks, professional bodies and societies. Both UHL and University staff are encouraged to engage in mentoring activities. Suitable mentors are available from both within and outside of the department.

MODERNISING SCIENTIFIC CAREERS (MSC)
UNDERGRADUATE AND POSTGRADUATE TEACHING

Both UHL and University staff within Medical Physics are active in University undergraduate and postgraduate teaching and research supervision. Lecture courses supported are listed below. Members of LRSS also provide UHL induction talks outlining the hazards of working with radiation.

<table>
<thead>
<tr>
<th>COURSE DESCRIPTION</th>
<th>VENUE</th>
<th>LECTURERS</th>
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<tbody>
<tr>
<td><strong>Medical Imaging</strong></td>
<td>Biomedical Sciences</td>
<td>Ms. Lisa Rowley</td>
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<tr>
<td>2nd Year BSc Biomedical Sciences</td>
<td>De Montfort University (approx. 170 students)</td>
<td>Mrs Nicola Booth</td>
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<tr>
<td><strong>Introduction to Medical Physics</strong></td>
<td>Department of Physics, University of Leicester (approx. 35 students)</td>
<td>Dr Emma Chung (Course leader)</td>
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<td>3rd year BSc/MPhys Physics</td>
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<td>Mrs Debbie Peet</td>
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<td>Lisa Rowley/Nicola Booth</td>
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<tr>
<td><strong>FRCR Part I exam training</strong></td>
<td>National revision course (approx. 50 students)</td>
<td>Dr Caroline Banahan</td>
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<td>Trainee Radiologists</td>
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<td>Mr Richard Raynor</td>
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<td>Dr Evangelia Kaza</td>
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<td>Dr Mark Horsfield</td>
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<td>Ms Anna Mason</td>
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<td>Dr Kumar Ramnarine</td>
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<td>Mrs Elizabeth Davies</td>
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<td>Mrs Nicola Booth</td>
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<td></td>
<td>Ms. Lisa Rowley</td>
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<tr>
<td><strong>FRCR Part I training</strong></td>
<td>University Hospitals of Leicester NHS Trust (approx. 10 students)</td>
<td>Dr Mark Horsfield</td>
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<td>Trainee Radiologists</td>
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<td>Dr Caroline Banahan</td>
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<td>Mrs Nicola Booth</td>
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<td>Ms. Lisa Rowley</td>
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<tr>
<td><strong>Non-Medical referrers of X-rays</strong></td>
<td>De Montfort University (approx. 20 students)</td>
<td>Mrs Elizabeth Davies</td>
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<tr>
<td>Post-registration nursing staff</td>
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STUDENT SUPERVISION

Members of Medical Physics provide undergraduate (BSc and i-BSc/i-MSc), MPhys, and PhD supervision. Many hold honorary academic appointments within the University of Leicester or De Montfort University.
Selected external talks

- Practical experience of equipment (plastics) becoming damaged through the use of decontamination products, Medical Device Safety Officer Meeting. J McDonald March 2017

- A focus on retrograde approach (Coronary Total Occlusion) Radiation Issues. D Peet, Leicester CT, October 2017

- Practical Radiotherapy Bunker Design. D Peet, Radiation protection Advisor (RPA) update, Bristol, May 2017

- Shear Wave Elastography (invited talk) K. Ramnarine, Ultrasound, Cardiff, December 2017

- ACS Route 2 - R Farley, IPEM Trainee Induction and Specialism day, January 2019

- Spontaneous Coronary Artery Dissection (SCAD) vs. healthy volunteers, F Almutairi, A Al-Hussaini, A-M Marsh, D Adlam, E Chung, K Ramnarine. Ultrasound, Cardiff, December 2017

- Brain tissue pulsation measurements for diagnosis of acute stroke: A pilot study. C Banahan et al British Medical Ultrasound Young Investigators Session, Ultrasound, Cheltenham 2018


- Diaphragm displacement during ABC controlled breath holding: is there an optimal inspiratory threshold? E Kaza, DJ Collins, M Orton, MO Leach, ISMRM, 2017

- Registration routes for Clinical Engineering, UK Contribution to Global Clinical Engineering day, J Mangat, October 2017


- Bristol Practical Radiotherapy Bunker Design. RPA update D Peet, May 2017


- Davies, E, Invited speaker: ‘Radiation Emergencies: What hospitals need to know.’ Association of University Radiation Protection Officers Annual Conference, 2018

- Shukla, V, Trainee Session Speaker: ‘Radiation Safety Culture. Radiation Protection Advisers Annual Conference’, 2018

- Bridges, A. Radiation Safety in CTO. Midlands CTO course, Birmingham, 2018
Appendix. A. Publications 2017-2018

BOOK CHAPTERS


PAPERS

- Adamson J, Cowe J. Modifying the manufacturer’s recommended Dark Adaptometry protocol for use in a clinical setting (poster), ISCEV (2018)

- Adamson J, Kempton J, Cone Dystrophy with Supernormal Rod Response (COD/SuperROD or CDSRR) (clinical case study), ISCEV (2018)


- Patel N, Horsfield MA, **Banahan C**, Thomas AG, Nath M, Nath J, Ambrosi PB, Chung EML, **Detection of Focal Longitudinal Changes in the Brain by Subtraction of MR Images. AJNR.** 2017. DOI: [https://doi.org/10.3174/ajnr.A5165](https://doi.org/10.3174/ajnr.A5165)

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