IPEM
Institute of Physics and Engineering in Medicine

2026

SCIENCE, TECHNOLOGY & ENGINEERING FORUM

ABSTRACT BOOK

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The NICE Health Tech assessment process and evidence generation for early use assessments

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Future of Medical Physics & Engineering, October 12, 2026, 11:00 - 12:05

Background The National Institute for Health and Care Excellence (NICE) HealthTech Guidance programme evaluates non-pharmaceutical technologies, including digital technologies, diagnostics and medical devices [3]. As part of a full lifecycle approach, topics may be evaluated via one of three routes; for early use (previously known as early value assessments), routine use or existing use (previously known as late-stage assessment). Each examines health technologies with different levels of evidence and varying degrees of existing implementation within the NHS.

The NHS 10 Year Health Plan [2] set out the ambition to accelerate the use of health tech in the NHS, particularly those relating to digital healthcare solutions and AI. The Early Use programme was launched in 2022 and aims to ensure promising and novel health technologies can be rapidly adopted into the NHS whilst additional evidence is generated, often utilising real world evidence and data [1]. Medical Physics, Clinical Engineering and Clinical Computing professionals (MPCE) are already involved in commissioning and generating evidence for several Early Use Topics [4,5].

Methods We will describe how the NICE HealthTech and Early Use programmes work, and the opportunities for the MPCE workforce to be involved. This would cover topic selection, the guidance process and evidence generation for early use topics.

Results To date, NICE has produced over 700 pieces of HealthTech guidance, with over 40 topics included in the Early Use programme (published or are in development). In the Early Use programme, over 120 technologies have been recommended for early NHS adoption since 2023. Examples include technologies used in radiotherapy treatment planning, AI tools to support diagnosis using various imaging modalities, and a wide variety of medical devices from robotic surgery devices to digital apps that deliver mental health support. The first technologies are expected to complete evidence generation and return to the routine guidance pathway in summer 2026. Thematic analysis has identified common evidence gaps that must be addressed before technologies can be considered for routine guidance [6]. MPCE colleagues are likely to be involved with evidence generation including on clinical effectiveness, adverse events, diagnostic accuracy, impacts on system resource use and user acceptance and experience.

Discussion NICE has a commitment to produce guidance that is timely, relevant and high quality to be useful to the NHS. There are many opportunities for MPCE colleagues to be involved at an individual topic level, or as experts in the wider evaluation programme.

Conclusion The NICE HealthTech guidance programme delivers a wide range of guidance for health technologies across a diverse range of topic areas. Many of these are directly relevant to MPCE colleagues, who may also be involved in evidence generation for some of the early use topics. By supporting safe innovation and smarter data collection, the Early Use programme is designed to help the NHS keep up with change, improve care and help patients access the care they need more quickly.

Key references

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[3] NICE, “About HealthTech Guidance”, Accessed from [https://www.nice.org.uk/what-nice-does/our-guidance/about-healthtech-guidance] on 18/03/26
[4] NICE, “Artificial intelligence (AI) technologies to aid contouring for radiotherapy treatment planning: early value assessment”, HealthTech guidance HTG695, 2023
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2 Undertaking the NHSE London Workforce Planning and Transformation Masterclass Programme: A Case Study in Medical Physics

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Workforce Transformation, Ashes & Boundary, The Point, October 12, 2026, 13:05 - 14:20

Background. Each year, NHSE London runs a highly competitive application process for healthcare professionals to take part in their 18-week Workforce Planning and Transformation Masterclass Programme. Our team was accepted onto this programme in 2026 with a project proposal focused on the transformation of the radiation safety and diagnostic radiology (RS & DR) workforce. The proposal was developed collaboratively by a team representing two large London trusts. Our aims are to build on the recent IPEM workforce intelligence report (1) that identified issues such as increased vacancy rate, insufficient trainee posts and the limited use of technologist roles in London. These findings align with the workforce statistics within our trusts, providing a clear focus for workforce transformation. A key aim of the project is to design a new practical workforce model for RS & DR, which is better aligned with clinical priorities and improves the efficiency, stability and agility of the services provided.

Methods We plan to undertake an in-depth analysis of skill-mix and create a competency framework to harness the potential for apprenticeship, technologist, radiographer and entry-level clinical scientist roles, and release time for qualified clinical scientists to provide scientific expertise to clinical services. We also want to build on existing work within the scientific community (2), to better understand how to prioritise the work of our teams focusing on identifying activities that we can a) safely stop doing, b) transform and undertake more efficiently or c) initiate as they add value to clinical services. We would like to understand how to better support our senior RS & DR staff to gain required accreditations (e.g. MPE, RWA and RPA). We also hope to learn from initiatives from other RS & DR departments and improve our services to maximise patient benefit and create opportunities for staff to reach their individual goals and potential.

Results, Discussion and Conclusion The findings of our work on the Masterclass Programme (March – October 2026) will be presented, along with reflections on our experience of using a formal workforce planning methodology within a medical physics setting.

What is the 6 Steps of Workforce Planning Methodology? (3)

The 6 Steps of Workforce Planning Methodology has been developed by Skills for Health.

The Six Steps Methodology to Integrated Workforce Planning is the only methodology cited in the NHS Long Term Workforce Plan. It is a practical approach to planning that ensures you have a workforce of the right size with the right skills and competence.

The Methodology identifies those elements that should be in any workforce plan, taking into account the current and future demand for services, the local demographic situation and the impact on other services, whilst helping you work to the budget you can afford.

The Six Steps Methodology offers:

• a systematic practical approach that supports the delivery of quality patient care, productivity and efficiency

• assurance that workforce planning decisions taken are sustainable and realistic

• a scalable approach, from small ward-based plans to large organisations

• a joined-up approach with social care, where the same approach has been adopted.

Key references

1. https://www.ipem.ac.uk/ipem-workforce-resources/workforce-intelligence/diagnostic-radiology-radiation-protection-resources/2024-diagnostic-radiology-and-radiation-protection-workforce-census-full-report/
2. 'Radiology Physics, Towards a Better Future', Jonathan Cole, SCOPE Spring 2026 Edition pg28-30 https://www.ipem.ac.uk/publications/scope/scope/scope-spring-2026/
3. Six Steps Methodology to Integrated Workforce Planning® | Skills for Health

3 Reflections on a university and employer collaboration to develop a new funded structured pathway to clinical scientist registration.

Dr Sarah Peel[1], Clare Anderson
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Workforce Transformation, Ashes & Boundary, The Point, October 12, 2026, 13:05 - 14:20

Background: The well publicised workforce challenges in Medical Physics (1) need novel solutions. The established training routes, whilst effective, do not provide the capacity or flexibility to train the required number of clinical scientists to deliver medical physics services in the future. Funding for a Level 7 qualification and the need for structured support for trainees and employers remain a barrier to clinical scientist training outside of the Scientist Training Programme (STP). To ensure our profession is open to a diverse range of candidates, it is a priority to explore funding opportunities for non-STP routes.

With both the NHS and universities facing a tight financial landscape, apprenticeships seemed an obvious solution, providing government funding via the Growth and Skills Levy (previously known as the Apprenticeship Levy) (2).

Methods: Medical Physics Education and Workforce Leads have been working in partnership with a university, with guidance from professional bodies, accreditation and EPA organisations, over the last 2 years to explore and develop a new funded pathway to lead to HCPC registration as a clinical scientist in Medical Physics.

1) We initially focused on using the Level 7 clinical scientist apprenticeship standard; however, Level 7 funding was effectively withdrawn in 2025.
2) We then designed a different pathway using the Level 6 Enhanced Clinical Practitioner (ECP) apprenticeship standard (3). At the time, this generic healthcare standard allowed the academic component to be delivered at Level 7, through a PGDip, and importantly would have opened access to funding for this via the Growth and Skills Levy. Unfortunately, in 2026, the government decided to stop allowing a L7 qualification to be delivered under the L6 ECP standard.
3) We have since explored the possibility of securing direct funding for flexible access to an MSc and structured support, delivered by a university partner.

Results: We have investigated different ways of funding the academic component of clinical scientist registration outside of the STP. We will present our attempts to find a solution and provide an honest reflection on our challenges.

Discussion: This work demonstrates the significant difficulties of using the apprenticeship model for our workforce, given the changing restrictions on accessing the levy.

Conclusion: A university-supported model has the potential to provide specialist education and training within a structured framework, where employers lack the sufficient time and resources to provide this in-house. Universities and employers however need a consistent guarantee of funding to commit to development of the programmes and their delivery in the long term.

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2. https://find-employer-schemes.education.gov.uk/interim/growth-and-skills-levy
3. https://skillsengland.education.gov.uk/apprenticeships/st0895-v1-2

4 Modernising an MSc in Medical Physics – Complementing an academic curriculum with foundation professional skills

Dr Silvia Pani[1], Mrs Catrin Ferioli[1], Dr Sarah Peel[2], Ms Clare Anderson[3], Mr Boota Singh[4], Professor Paul Sellin[1], Prof Daniel Doherty[1], Ms Liz Adams[1,5], Melanie Cunningham[5], Mr Graham Wilson[4]
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Workforce Transformation, Ashes & Boundary, The Point, October 12, 2026, 13:05 - 14:20

Background The MSc in Medical Physics at our University is accredited by the Institute of Physics and Engineering in Medicine (IPEM) and has successfully trained over 1,000 medical physicists.

Discussions with employers highlighted the need to strengthen the development of professional skills beyond the purely academic and technical content. In parallel, the exponential progress of AI showed the need to adapt teaching and assessments to cover responsible use of AI tools.

Both these considerations spurred a review of the programme content in order to better prepare students for their future careers.

Methods The programme content was reviewed in the light of discussion with employers and feedback from students, as well as internal discussions and university guidance regarding the use of AI.

Whilst bearing in mind the need to preserve academic rigour and strong physics foundations, we refined the curriculum in order to better prepare students for a fast-moving, interdisciplinary profession.

Results Following review of employers' feedback, we have developed a new module named 'Professional Skills for Medical Physicists' which incorporates an introduction to many of the key soft skills that are increasingly required within the workplace to complement technical and academic knowledge. These aim to develop personal attributes and values which will assist the students in their careers as professionals and with the increasing need to collaborate productively within a multidisciplinary healthcare team and to advocate for safe and effective healthcare[1]. These skills are aligned with the core competencies required for registration as a clinical scientist, but also equip students with essential tools for roles in other areas such as academia or industry.

The module builds on topics that were already covered within the MSc but with a strongeremphasis on scientific writing, responsible use of generative AI tools, communication skills, ethical principles and radiation safety. These support the practical and experimental skills gained within the radiation laboratory.

A specific series of lectures have been developed around scientific communication and patient engagement, and it is hoped that this will broaden the perspectives of the students, in line with other healthcare professional training programmes.

Discussion The newly-developed module will enhance current MSc students' professional skills, but could, in the future, be offered to individuals seeking transition from a more academic background to a clinical environment. Module evaluation and student feedback will allow further adjustment of the module content.

Conclusion The "Professional skills for medical physicists" module will launch in 2026/27, as a way to support Medical Physics MSc students with a broader understanding of the clinical and academic context in which they will operate.

Key references.

1) T. Kron et al (2026), *Soft skills for medical physicists: Evolving a profession.* Journal of Applied Clinical Medical Physics 27(3). DOI: https://doi.org/10.1002/acm2.70531

5 Stronger Together: A Light-Touch Regional Approach to Training Capacity and Retention in Medical Physics

Mr Alex Goodall[1]
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Workforce Transformation, Ashes & Boundary, The Point, October 12, 2026, 13:05 - 14:20

The Problem: Workforce pressures within Medical Physics departments are contributing to a cycle that affects both training capacity and staff retention. Limited staffing means that current teams often struggle to find sufficient time to support STP trainees effectively. At the same time, training numbers across trusts in Yorkshire and the Humber are not meeting the levels required for service sustainability, both in terms of replacement and future growth. This has led to a situation where reduced training capacity risks further exacerbating workforce shortages, placing additional strain on existing staff and limiting opportunities for trainees.

The Intervention: To address these challenges, a regional approach was developed to centralise selected aspects of training. The aim was to make more efficient use of trainer time by delivering shared training activities to larger groups of trainees across multiple trusts. Several initiatives were introduced:

Regional PET-MR Day: A dedicated training day was organised, bringing together STP trainees from across the region. The programme was designed to support completion of specific training activities in both Nuclear Medicine and Imaging with Non-Ionising Radiation. It included observation of PET-MR quality assurance in the morning, followed by an interactive workshop on MRI QA analysis in the afternoon.

Regional Induction Day: Initially developed just for Medical Physics trainees, this event expanded to include all STPs in the region. The day provided an overview of the training programme, guidance on completing competencies, and practical sessions on reflective writing, health and wellbeing, and professional use of social media. More recent events have been organised and delivered solely by the Yorkshire and the Humber Healthcare Science Trainee Network with the aim of addressing the STP Core Module Training Activities.

Regional Open Day: Current trainees from across the region collaborated to design and deliver an open day for prospective applicants. Hosted in Sheffield, with plans to rotate between trusts, the event was delivered in a hybrid format to maximise accessibility. It combined presentations with interactive workshops to give attendees insight into the training programme and roles within Medical Physics.

Regional US Physics Support: Sheffield has provided ultrasound (US) physics training and ongoing support for rotational and specialist STPs across the region as many centres find it challenging to accommodate this locally. In Hull and Leeds, efforts are underway to build up ultrasound physics support, with the aim of contributing and ultimately, sharing the training workload across the region.

Outcomes and Benefits: These initiatives have been well received by trainees, who valued the opportunity to meet peers from across the region and build professional networks early in their training. This was particularly helpful ahead of extended academic placements.

The shared delivery model has reduced the training and organisational burden on individual departments, while the involvement of trainees in planning and delivery has supported engagement and sustainability. Rotating responsibility for events between trusts also helps distribute workload more evenly across the region.

Future Developments: Further work is planned to build on this regional approach. This includes encouraging additional trusts to develop similar shared training events, particularly for rotational competencies where larger cohorts allow greater efficiency.

Regular meetings between MRI training leads have also been established to share good practice and explore further opportunities for collaboration, with the intention of extending this model to other specialisms.

There are also plans to broaden the scope of the regional open day to include prospective applicants to Clinical Engineering and Scientific Computing programmes, allowing a wider group to benefit from the initiative.

6 Transforming difficult airway planning using point-of-care 3D design and manufacture

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Engineering Systems & Design, 1864 Suite, October 12, 2026, 13:05 - 14:20

Background

Difficult airway management during surgery presents risks associated with significant morbidity, mortality, and procedure abandonment. Conventional assessment and two-dimensional imaging have limited predictive accuracy (Shiga et al., 2005). The NAP4 report identified many major airway complications as preventable with improved planning (Royal College of Anaesthetists, 2011), and failed intubation can lead to surgical abandonment. Three-dimensional (3D) modelling and virtual endoscopy improve anatomical understanding, influencing airway management decisions (El-Boghdadly et al., 2017; Han et al., 2016), and enable procedure simulation and patient-specific instrumentation, but routine clinical integration remains limited.

Methods

A structured airway planning pathway was developed utilising CT-based segmentation to produce interactive 3D visualisation, virtual endoscopy, patient-specific silicone airway models for procedural rehearsal and patient-specific airway conduits for intraoperative use. These were reviewed within multidisciplinary team discussions to support planning and decision-making. The workflow was applied to complex airway cases and designed to operate within routine clinical timelines.

Results

Patient-specific 3D planning improved understanding of airway anatomy and supported safer procedural strategies. In multiple cases, it reduced the need for invasive trial endoscopy. Critically, the pathway enabled surgery in patients with previously failed or abandoned procedures. Across >52 complex airway cases, clinicians reported improved first-pass intubation success, reduced abandonment, and increased confidence. A representative mucopolysaccharidosis (MPS) case demonstrated this impact: following two failed intubations and abandoned procedures, simulation-based rehearsal enabled successful first-pass intubation and safe completion of surgery.

Discussion

This approach shifts airway management from reactive to proactive planning. By enabling visualisation and rehearsal, 3D technologies support risk anticipation and strategy optimization before intervention. The ability to avoid invasive trial endoscopy, and to effectively convert previously non-treatable cases into successful interventions represents a significant clinical advancement, consistent with published evidence (El-Boghdadly et al., 2017; Ahmad et al., 2015). The pathway also improves communication, training, and operational efficiency.

Conclusion

Point-of-care 3D design and manufacture can transform difficult airway management. It demonstrably reduces procedure abandonment, avoids invasive trials, and improves outcomes in high-risk patients, and therefore has potential for wider adoption in surgical care of patients with complex and difficult airways.

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3. Han S, et al. J Clin Anesth. 2016;33:548–555.

4. Royal College of Anaesthetists. NAP4 Report. 2011.

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7 Quantifying Right Ventricular Mechanics Using Pressure–Volume Loop Analysis in Patients Undergoing Balloon Pulmonary Angioplasty

Miss Amy Edwards[1], Dr Stephen Hoole[2], Dr Gerry Coghlan[2,3], Professor Paul White[1,2]
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Research & Innovation, The Club Suite, October 12, 2026, 13:05 - 14:20

Background.
Chronic thromboembolic pulmonary hypertension (CTEPH) is characterised by persistent obstruction of the pulmonary vasculature, leading to progressive right ventricular (RV) dysfunction. Balloon pulmonary angioplasty (BPA) is a novel treatment for inoperable CTEPH [1,2,4] but existing studies rely on load-dependent measures derived from imaging or conventional catheterisation, limiting assessment of RV adaptation. Pressure–volume (PV) loop analysis provides gold-standard, load-independent assessment of RV–pulmonary artery coupling, contractility, and diastolic function [3,5]. This study aimed to characterise changes in RV mechanics following BPA using PV loop analysis.
Methods.
Patients with inoperable CTEPH undergoing BPA were recruited at the UK's sole specialist centre (n = 15). RV PV loops were acquired using a conductance catheter before and after BPA treatment. These were used to derive load-independent indices including end-systolic elastance (Ees), effective arterial elastance (Ea), ventricular-arterial coupling (Ees/Ea), preload recruitable stroke work (PRSW), end-diastolic PV relationship (EDPVR), and rates of pressure change (dP/dt±). Standard haemodynamic parameters were also recorded. Pre–post comparisons were performed using paired statistical analyses ($p<0.05$).
Results.
Conventional haemodynamic parameters demonstrated significant reductions in end-systolic pressure and end-diastolic pressure. The study revealed significant reductions in afterload (Ea). Indices of contractility, including PRSW and dP/dt+, were significantly reduced. Diastolic function improved, with significantly reduced EDPVR and increased dP/dt−, indicating reduced stiffness and improved relaxation. Ventricular–arterial coupling (Ees/Ea) showed a non-significant increase from 1.38 to 1.57.
Discussion.
This study demonstrates that BPA induces complex RV mechanical adaptation not captured by conventional clinical metrics. The reduction in contractility indices alongside decreased afterload likely reflects reduced compensatory RV hypercontractility rather than dysfunction. Reduced RV stiffness and improved relaxation indicate enhanced diastolic function and compliance. Together, these findings suggest improved RV mechanical efficiency, with a trend toward improved ventricular–arterial coupling.
Conclusion.
BPA reduces RV afterload, accompanied by normalisation of contractile demand and improved diastolic function. These changes reflect restoration of RV mechanical efficiency and cannot be fully characterised without pressure–volume loop analysis. PV loop assessment provides a valuable tool for evaluating and optimising BPA treatment strategies. These findings show how advanced haemodynamic measurements can support clinical decision-making in real time and therefore, optimise BPA outcomes.

Key References

[1] Aggarwal et al. Status and Future Directions for Balloon Pulmonary Angioplasty in Chronic Thromboembolic Pulmonary Disease With and Without Pulmonary Hypertension: A Scientific Statement From the American Heart Association, 2024
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8 Acoustic noise reduction techniques for paediatric proton beam therapy planning

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Research & Innovation, The Club Suite, October 12, 2026, 13:05 - 14:20

Introduction

MRI scans are often very loud, due to Lorentz forces acting on gradient coils, and this can be very distressing for paediatric patients (1,2). In proton beam therapy (PBT) planning, this anxiety is compounded by immobilisation masks, flat couches, and loud sequences like diffusion-weighted imaging. These factors can lead to scan abortion, longer scan times, motion artifacts and increased use of general anaesthesia. Acoustic noise can be reduced by manipulating gradients, lowering the gradient amplitude and slew rate to minimise Lorentz forces. The aim of this work is to investigate two Philips gradient noise-reduction techniques, ComforTone and SofTone (3) and assess the implications on both image quality for PBT planning and participant experience.

Materials and methods

A regional survey was distributed to MR physicists supporting sites to assess current use of acoustic noise reduction techniques and barriers to implementation. At our institution, the routine paediatric brain protocol for PBT planning was selected for initial evaluation on a Philips Ingenia 1.5T system. Initial testing used an ACR phantom (4) with standard T1 and T2 sequences (AP and RL phase encoding directions), alongside ComforTone and SofTone variants in a clinically relevant setup. Scans were repeated across three sessions using default and reduced-noise gradient modes (regular), following ACR analysis guidance (4). The same noise-reduction methods were then applied to the routine paediatric brain protocol, which included T1w gradient echo, T2w spin echo, diffusion weighted imaging, and MR angiography sequences, comparing original, ComforTone (moderate reduction), and SofTone (maximised reduction) sequences. These sequences were optimised to maintain scan time and clinical feasibility for PBT, following IPEM guidance for radiotherapy (5). Acoustic noise was measured using an Optimic 1155 optical microphone (6) attached to a CIRS head distortion phantom (7), recording maximum C-weighted RMS sound levels alongside geometric distortion measurements. A healthy volunteer was then scanned with original and optimised sequences in a randomised and blinded sequence ordering and rated the loudness (L) and unpleasantness (U) of the scan (1–10; 10 being loud and unpleasant).

Results

The initial survey indicated that usage of acoustic noise reduction was variable (11/26 centres using noise reduction techniques), with the primary use case being paediatric and foetal imaging, secondary to dementia and autistic patients. Centres reported a lack of clinical request as the primary reason for not using the techniques. A poor understanding of image quality implications due to lack of testing was common amongst centres. For prospective evaluation at our centre, initial ACR analysis indicated no variation in SNR, uniformity, ghosting, and geometric accuracy across three independent scanning sessions, with all measurements lying well within ACR tolerances (Figure 1). Measurements of acoustic noise for the optimised sequences (see Figure 2a and b) demonstrated a mean reduction of 17.76 dB(C) relative to the original clinical sequences, and a maximum reduction of 19.8 dB(C) for the T1 sequence (corresponding to a ten-fold reduction in sound pressure level). All the sequences passed the CIRS geometric distortion check with an average distortion <2.5mm. Initial healthy volunteer imaging also showed a noticeable reduction in acoustic noise based on subjective scoring, with no change in acquisition time, see Figure 3 captions. Preliminary qualitative analysis of the T1w and T2w sequences demonstrate acceptable image quality across all variants of each sequence (Figure 3), with practically the same acquisition time. At this optimisation stage, SofTone images showed slight variation in contrast and SNR corresponding to a longer TR in the T1w images (Original: 8.3ms, SofTone: 16ms) and TE in the T2w images (Original: 250ms, SofTone: 306ms). Correspondingly, the T1w sequence shows signal gain, whilst the T2w sequence demonstrates some signal loss.

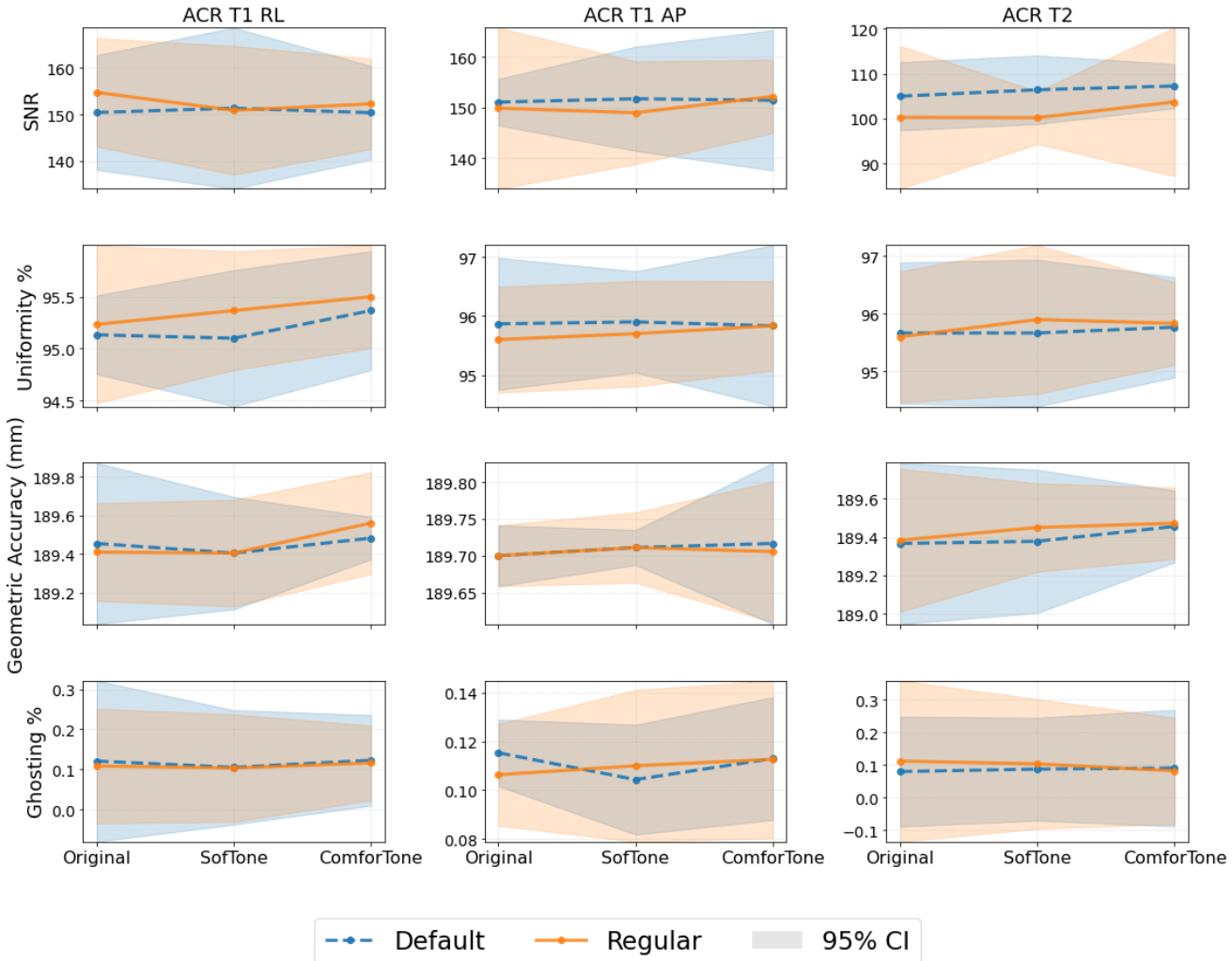
Conclusions

The survey demonstrated considerable variability in the adoption of acoustic noise reduction techniques, largely limited to paediatric and foetal applications. This highlights a need for further evidence-based evaluation of clinical benefit and standardised assessment of image quality impact to support wider and more consistent

implementation. Evaluation of phantom measurements showed no significant difference in quantitative image quality using noise reduction techniques. The acoustic noise measurements indicated that considerable reductions in acoustic noise are possible, equivalent to over 80% reduction. These are reflected in the subjective interpretation, suggesting that such reductions can make a noticeable difference to scan experience, with little to no increase in scanning duration. Initial volunteer image quality assessment demonstrated minor differences, with some variation in contrast seen for the T2w SofTone sequence. Additional optimisation is underway based on these results. In summary, SofTone and ComforTone are promising techniques in improving paediatric patient compliance for PBT planning. Further work will evaluate optimised sequences with radiologist and oncologist blinded image review before assessment in paediatric patients.

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interval across the three sessions.

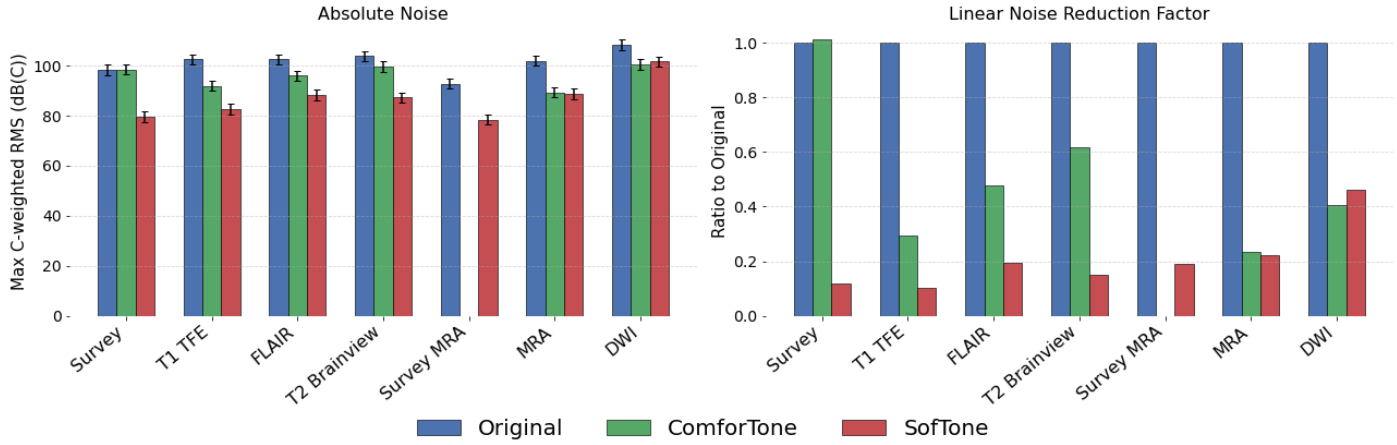


Figure 2 - (a) Max C-weighted RMS measured across all clinical sequences. (b) Ratio of linearised sound pressure levels to original sequences.

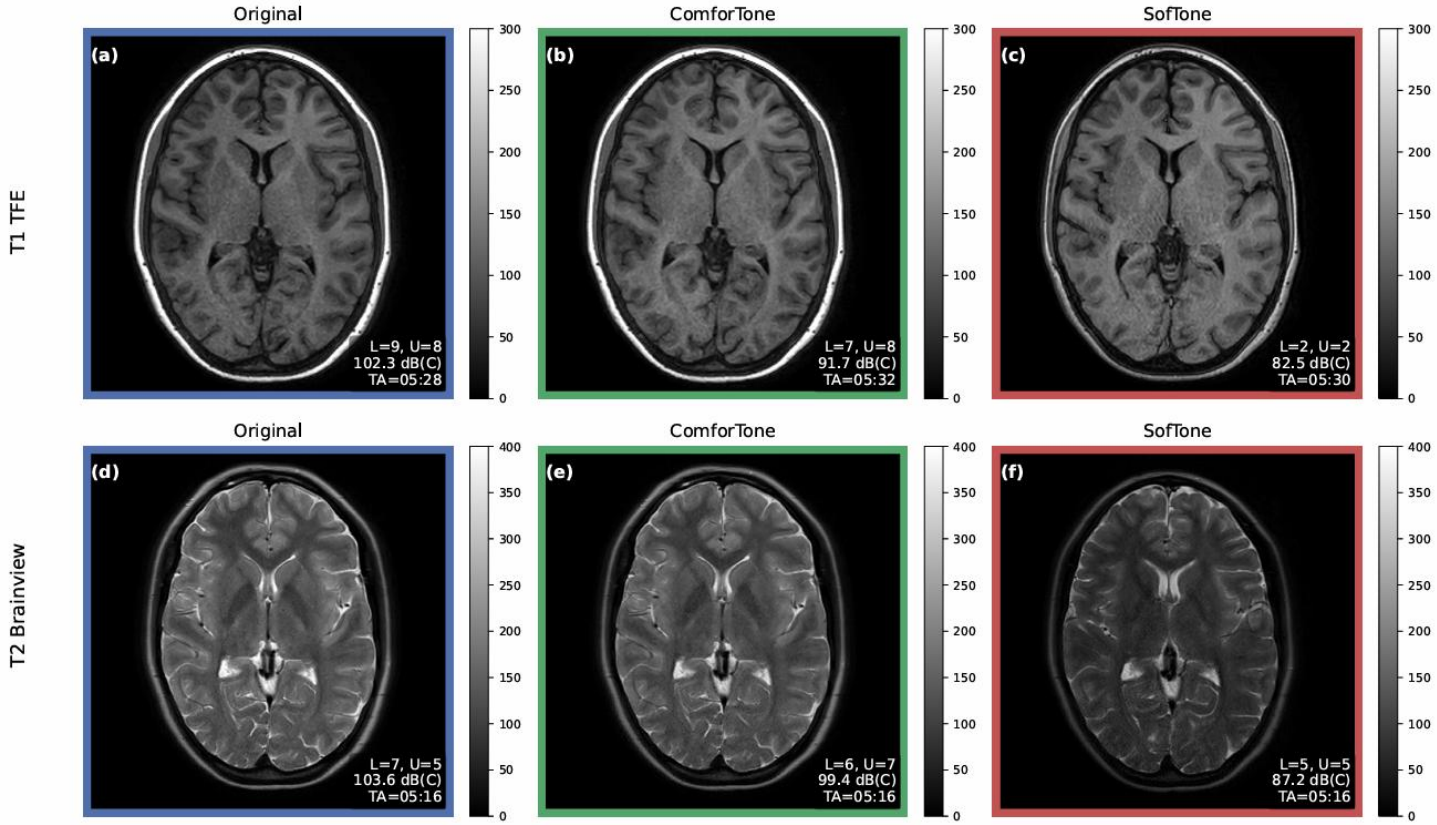


Figure 3 – Axial level of the lateral ventricles (body/atrial region), around the basal ganglia to centrum semiovale transition. Original, ComforTone, and SofTone images from a healthy volunteer across T1 and T2 acquisitions. U = unpleasantness, L = loudness from perceived volunteer assessment.

9 An emerging role for radiotherapy physicists: can they help lower patient anxiety?

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Research & Innovation, The Club Suite, October 12, 2026, 13:05 - 14:20

Background

Anxiety in radiotherapy patients is common [1] and patient information and education interventions are proven to lower anxiety [2]. The role medical physicists have to play in direct patient care has only recently started to be investigated. Atwood et al. [3] showed a significant reduction in patient anxiety through their "physics direct patient care" (PDPC) initiative. It is uncertain whether this impact will be translated into the NHS. This work explores whether medical physicists in NHS radiotherapy departments have a role in lowering patient anxiety.

Methods

A phase III, randomised controlled trial: RAPPORT (Reduce Anxiety for Patients with Physicist appOintments in RadioTherapy), was designed and ethical approval given. 60 participants will be recruited, and randomised 1:1 (stratified by gender) to the intervention or control arm. Those on the intervention arm will receive an additional 20-minute consultation with a member of the radiotherapy physics team to discuss the technical aspects of their care, with the control arm receiving the standard of care (no additional technical information). The intervention will be on the day of first treatment, with questionnaires administered at CT, first treatment, and last treatment.

Results

61 patients were recruited. 31 received the intervention, and 30 "standard of care" where no additional technical information was given. Patient follow-up concludes on the 20/04/2026, with data analysis taking place after. Preliminary data analysis has shown that patients receiving the intervention have lower anxiety at the end of their treatment. 40% of patients present with clinically relevant levels of anxiety, in line with published literature for radiotherapy patients.

Conclusion

A randomised controlled trial has been successfully run as part of a HSST DClinSci research project. The RAPPORT trial sought to examine whether there is value in a patient-facing role for radiotherapy physicists and is the first study in the UK exploring this. Preliminary results support published literature, that physicist communication with patients about their care is a value-adding undertaking. Final results will be available shortly. This work forms part of an examined doctoral programme, with examination occurring after STEF 2026, I kindly request an oral presentation (if offered) is not filmed.

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10

Automation of dosimetric audit of cervix radiotherapy

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Research & Innovation, The Club Suite, October 12, 2026, 13:05 - 14:20

Background

Clinical audit is requirement under IR(ME)R2017with the aim of ensuring clinical services meet required standards. Within radiotherapy there is vast quantities of data which can be accessed automatically when in an appropriate format and within a suitable system. Brachytherapy can be complex to audit due to the varied nature of individual treatments with the combination of different external beam radiotherapy (EBRT) regimes. This work explores the benefits of implementing an automated routine audit within gynaecological image guided brachytherapy (IGBT) to quantify the dosimetric parameters of generated plans against the documented clinical standards.

Methods

Many patients treated for cervix cancer are treated following the protocol and dose constraints developed through the EMBRACE trials using a combination of EBRT and multiple customised IGBT treatment fractions. The overall dosimetric constraints are assessed through equivalent dose in 2 Gray fractions (EQD2) for the combined EBRT and IGBT.
A methodology has been developed locally with the aim to:

- Ensure all EBRT and IGRT doses are available within the same clinical system (Varian Eclipse TPS)
- Automatically extract required dose parameters based on list of patients as the only input
- Automated analysis including comparison to recommended clinical standards (from EMBRACE trial [1] and RCR guidance [2])
- Automated report generation including statistical analysis and plots of results for review

Results

All doses are routinely transferred from the brachytherapy planning system to Eclipse as part of the routine process through the DICOM standard. An ESAPI script was developed which extracts data from the Eclipse TPS in a standardised format based on an input text file containing patient IDs. Data extraction takes approximately 1 second per treatment plan. One year of data takes 1-2 minutes.

An automated python script was developed to analyse extracted data. This script converts doses reported by the TPS into EQD2 for the EBRT and IGBT plans. These are summed to give total doses for each patient. These are compared to the recommended standards, summary statistics produced and plots generated. A separate spreadsheet is generated containing the calculated results and images of plots are saved as individual files. The script compiles these into a report in the MS Word document format, saves this for the user to review. The analysis and report generation script takes approximately 2 minutes to run. The user can review, add comments, and perform any additional analysis if required using a generated spreadsheet with cumulative EQD2 doses.

Conclusion

The time taken to complete an annual dosimetry audit of combined brachytherapy and EBRT doses is reduced by around 80% by automating the data extraction, and routine analysis processes. This is possible to implement within the routine service using clinically available tools to increase the confidence in maintaining the expected clinical standards.

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11 A regional planning audit using Elekta Proknow

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[1]Mid And South Essex NHS Foundation Trust

Research & Innovation, The Club Suite, October 12, 2026, 13:05 - 14:20

A regional planning audit using Elekta Proknow

Background: Elekta Proknow is a digital service allowing patient data (including RT plans, structure sets and images) to be remotely stored and anonymously shared between organisations. The platform's analysis tools enable comparison of individual plans or collections against Dose Volume Histogram (DVH) scorecards, and production of population histograms or scatter plots.

Methods: Our physics department arranged a regional dosimetry audit involving six centres across five NHS trusts, all sharing the same regional network's clinical protocols. This audit employs the IPEM Proknow Technical Oversight Group (PTOG)'s scorecards, in line with recent national audits making use of Proknow. Our radiotherapy physics department provided anonymised images of one patient prescribed external beam treatment for each of three sites - head & neck 65Gy/30#, lung SABR 55Gy/5#, and oesophagus 50Gy/25#. CTVs and OARs were contoured at our centre, and each participating centre instructed to plan "as usual", including derivation of PTVs. Completed plans were uploaded to proknow and added to per-site regional collections for analysis of:

- Whether any centres in the region are outliers regarding target or OAR doses.
- Whether particular target/OAR objectives or tolerances commonly fail.
- Which observed differences between centres are justifiable tradeoffs (for example, sparing OAR A at the expense of OAR B), and which are objectively better/worse. (for example, centre A has lower doses to OARs A and B with no apparent downsides vs centre B)
- Whether regional protocol is being followed consistently.
- Inconsistent nomenclature and misalignment with national nomenclature standards.

Results and discussion: Analysis of the data is ongoing, but significant differences in practice have been identified as shown in Figure 1, a scatterplot with linear regression which demonstrates a strong inverse correlation between spinal cord and parotid doses for the head & neck plan, meaning different centres in the region are making different clinical decisions. Full results will be analysed and prepared before the meeting.

Conclusion: We will present the methodology and outcomes of our centre's experience conducting a regional audit with Proknow leading to actionable suggestions for improvements in practice. This provides a case study of how "big data" cloud tools can be leveraged by clinical scientists to develop and improve services. Our methodology and challenges encountered can potentially assist other centres in using proknow to its full potential.

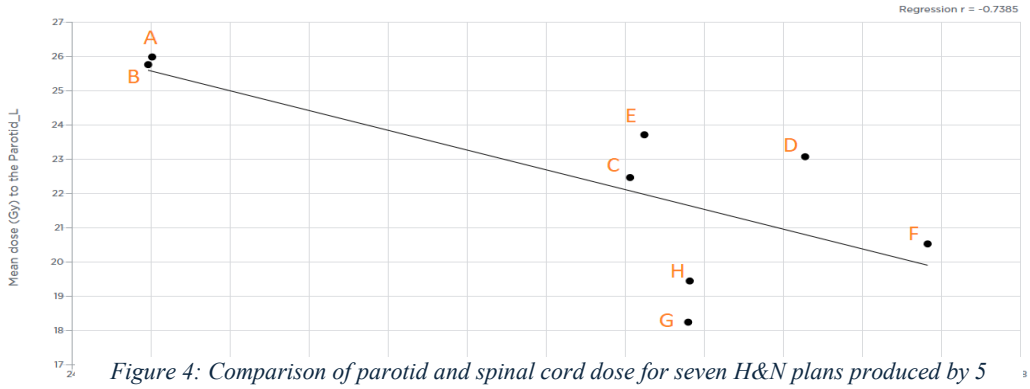


Figure 4: Comparison of parotid and spinal cord dose for seven H&N plans produced by 5 regional centres.

12

SUBCONSCIOUS COGNITIVE BIAS IN RADIOTHERAPY LINAC FAULT DIAGNOSIS: A SURVEY OF UK RADIOTHERAPY ENGINEERS

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Leadership & Workplace Culture, Ashes & Boundary, The Point, October 12, 2026, 14:20 - 15:15

Background
Medical linear accelerators (Linacs) require rapid and accurate fault diagnosis to maintain treatment continuity. Radiotherapy engineers often work under time pressure, relying on experience, pattern recognition, and troubleshooting to resolve interlocks, where errors can impact treatment delivery (2). However, similar fault codes may have different causes, increasing the risk of misdiagnosis. Decision-making in such environments is influenced by cognitive heuristics, including anchoring, availability, and confirmation bias (8,3). While cognitive bias is known to affect diagnostic accuracy in medicine and human factors research (1,5,6), its role in radiotherapy engineering remains poorly characterised. This study evaluates decision-making patterns and the influence of subconscious bias in troubleshooting.

Methods
An anonymous cross-sectional survey was distributed to UK radiotherapy engineers over six weeks, combining two identical surveys to yield 70 participants (69 for one item). Respondents had varied experience: 10.0% (0–2 years), 12.9% (3–5 years), 28.6% (6–10 years), 20.0% (11–20 years), and 28.6% (>20 years). The questionnaire assessed fault-response behaviour, experience, time pressure, intuition, and awareness of cognitive bias using Likert-type scales. Items were developed based on established literature in cognitive bias, human factors, and clinical decision-making, reflecting key constructs such as heuristic reasoning, diagnostic error, and the influence of time pressure (1,3,5,6,8). Responses were analysed as ordinal variables and grouped a priori (e.g., “Always/Often/Sometimes” vs “Rarely/Never”) in line with established guidance (7). Descriptive statistics were calculated using valid-response denominators, with 95% confidence intervals estimated using the Wilson method (9). Exploratory associations with incorrect initial assumptions were analysed using proportional odds ordinal logistic regression (4), with results interpreted cautiously.

Results
70 responses were analysed using valid-response denominators. Experience- and pattern-based troubleshooting behaviours were common: 48/69 respondents (69.6%) reported having a “go-to” fix for recurring faults, and 49/70 (70.0%) reported applying familiar fixes without full verification at least sometimes. Time pressure was highly prevalent, with 65/70 respondents (92.9%) reporting that it influenced their first troubleshooting action at least sometimes, and 58/70 (82.9%) reporting clinical workflow pressure often or always.
Intuition was used at least occasionally by 53/70 respondents (75.7%). Thirty-nine respondents (39/70, 55.7%) reported that an initial assumption had later been found incorrect due to reliance on previous patterns. This was observed across all experience levels: 57.1% in 0–2 years, 66.7% in 3–5 years, 70.0% in 6–10 years, 50.0% in 11–20 years, and 40.0% in 20+ years. Urgency-related shortcuts were reported by 24/70 respondents (34.3%), who stated that urgency often or sometimes led them to skip diagnostic steps.
Awareness of cognitive bias was high, with 60/69 respondents (87.0%) at least somewhat aware that subconscious bias could affect engineering judgement, and 49/70 (70.0%) agreeing or strongly agreeing that subconscious bias influences radiotherapy engineering decisions. Exploratory analysis suggested a potential association between time pressure and incorrect initial assumptions; however, this relationship appeared to be influenced by other behavioural factors, indicating that time pressure co-exists with multiple aspects of decision-making.

Discussion
The findings suggest that cognitive biases may influence Linac fault diagnosis under time pressure. The high prevalence of ‘go-to’ solutions suggests that engineers frequently rely on heuristic decision-making, using experience-based shortcuts consistent with fast, intuitive reasoning models (3,8). While such approaches are efficient and often necessary in time-critical clinical environments, they may reduce reliance on systematic diagnostic processes, as reflected by the high rate of incorrect initial assumptions (1,5). These behaviours reflect practical adaptations to complex, high-pressure clinical environments rather than simply poor decision-making

(6). However, when similar interlocks arise from different underlying causes, reliance on pattern recognition alone may contribute to misdiagnosis and prolonged troubleshooting, with potential clinical impact (2).

Conclusion

Cognitive bias may influence Linac fault diagnosis, with reliance on experience and intuition being common in radiotherapy engineering practice. While efficient, such approaches may introduce variability in diagnostic accuracy. Structured diagnostic frameworks and bias-awareness training could be integrated into the IPEM training scheme and the Scientist Training Programme (STP). Integrating human factors into radiotherapy engineering practice could improve troubleshooting reliability, reduce downtime, and ultimately support patient care.

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13

Quantifying medical device risk for replacement planning

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Engineering Safety & Governance, 1864 Suite, October 12, 2026, 14:20 - 15:15

Background:
Across the NHS safe clinical practice relies on the timely replacement of key medical equipment. Relatively standard medical devices (or 'assets') used across patient pathways, such as ultrasound machines, operating tables, patient monitors, amongst many others, cost in excess of £5000. Therefore they are classed as capital assets and as such require annual Trust capital financial allocation to replace, alongside competing estates and digital projects.
A review of other Trusts methodology found that there is not a standardised process across the NHS for medical equipment replacement planning. With the increasing cost of medical equipment, an increasing number of capital assets on the Trust inventory and insufficient funding available to cover the costs of replacing all required assets, the prioritisation process needs to be reviewed to ensure that the Trust is replacing the correct equipment at the correct time.
We propose, and literature suggests[1], that there are multiple factors influencing the degree of risk a medical device poses whilst in use and these factors could, in part, be accounted for in an objective way to determine the clinical risk and/or Trust strategy for replacement.
Methods:
Existing assets will be scored against technical, clinical, financial and sustainability criteria with a matrix-based approach.
Technical scoring can be done by reviewing the equipment record on the Trust asset register. Clinical scoring will be weighted, following answers to a series of questions relating to the device, flagged as a risk by the clinical team.
Results:
Considering retrospective data, technical scores generated from previously replaced equipment have been compared. Differences in scores of the assets replaced via planned replacement versus emergency replacement are significant (P= 0.037).
Devices that were replaced with emergency funding had higher technical risk scores indicating that the replacement need could have been predicted, and therefore planned for, more effectively by considering this element in the prioritisation process.
Technical score alone provides some indication to the level of risk, but cannot be used as a sole indicator of priority for replacement. Other factors need to be considered and the weighted scoring of these validated.
Discussion:
For individual equipment requests, outside a planned rolling replacement program, the aim of this project is to improve the objectivity of risk assessment for replacement requirements to reduce potential bias.
So far this project has

- Provided improved information to directorates with regards to what assets on the Trust inventory are due for replacement via a 'Technical risk profiler' webpage
    - Proactive approach to equipment replacement using objective measure of risk
    - Reduced subjectivity/ potential bias in equipment replacement priorities

Conclusion:
This project is ongoing and with continued work we aim to validate and improve the current methodology used for calculating technical and clinical risk;

- considering weighted priority scoring across different domains.
- Further quantify replacement need by factoring in digital, financial and sustainability parameters.
- Look to consider how other Trust processes/systems can feed into this exercise to reduce duplication of information across different platforms

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14 Strengthening Clinical Engineering Services Through Accreditation: The Role of BS 70000

Miss Stella Otomewo[1], Professor Paul White[1,2]
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Engineering Safety & Governance, 1864 Suite, October 12, 2026, 14:20 - 15:15

Background: Clinical engineering services are essential to patient safety through the safe management of medical devices, yet assurance arrangements across the NHS remain inconsistent. In pathology, accreditation to ISO 15189:2022 has been associated with improved governance, reliability and quality of outcomes. An equivalent UK framework now exists for clinical engineering in BS 70000, the UKAS accreditation standard derived from ISO 15189 principles. Unlike certification to ISO 9001 and 13485, which confirms the presence of a quality management system, accreditation to BS 70000 provides independent assessment of technical competence, staff capability, measurement traceability, service delivery and clinical risk, representing a higher level of scrutiny.
The Kingdon Review of Children's Hearing Services further highlighted the fragility of technical services operating without robust governance and independent assurance, demonstrating how variability, weak oversight and limited challenge can lead to patient harm. This reinforces the limitations of relying solely on internal quality systems and certification.

Methods: A review of ISO standards, UKAS guidance, published evaluations and national reviews was undertaken, comparing certification (ISO 9001, ISO 13485) with accreditation frameworks, particularly BS 70000. Evidence from ISO 15189-accredited pathology services and findings from the Kingdon Review were used as transferable models for clinical engineering.

Results: ISO 9001 supports organisational quality management, and ISO 13485 strengthens control of medical device processes and regulatory compliance; however, certification does not assess technical competence or service performance. BS 70000 introduces external scrutiny of competence and outcomes, supporting standardisation, resilience and early identification of risk. CUH Clinical Engineering was an early NHS adopter of BS 70000, demonstrating feasibility and benefits including strengthened governance, clearer accountability and improved assurance of staff competence.

Discussion: Certification strengthens internal system control but does not verify technical competence. Accreditation to BS 70000 complements certification by assuring the implementation of the quality management systems, validating competence, comparability, and enhanced risk identification. This combined approach is particularly important in high-risk healthcare environments where device performance directly affects patient outcomes.
Pathology services provide a strong precedent, with ISO 15189 accreditation linked to improved governance, consistency, and risk management. Adopting a similar model to BS 700000 in Clinical Engineering could enhance standardisation, accountability, and safety across the device lifecycle. The Kingdon review demonstrated how the lack of oversight has led to serious long-term clinical consequences and the relevance of independent assurance.

Conclusion: Certification and accreditation are therefore distinct but complementary. Aligning ISO 9001 or 13485 certification with BS 70000 accreditation provides a proportionate and robust assurance framework for clinical engineering services, directly addressing service fragility identified in national reviews and supporting safer, more reliable patient care.

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15

Investigating Dose Accumulation for Reirradiations Using Single Point and 3D Biological Doses for D(max) and Volume Dose Constraints

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Applied Radiotherapy, The Club Suite, October 12, 2026, 14:20 - 15:15

Background. The number of reirradiation treatments is increasing globally due to advances in radiotherapy and increasing life expectancy [1]. To perform these treatments safely, the toxicity of the organs at risk must be assessed through dose accumulation of current and previous courses of treatment. There is a large uncertainty associated with the dose accumulation process. The aims of this project were to better standardise the reirradiation pathway, based on international practice, to reduce the risk of human error and provide a more accurate summation of the dose [2-5]. Additionally, there was the aim of producing accumulated volumetric dose information that could be used to help guide clinician's decision making.

Methods. The current spinal point dose accumulation method (point dose) was compared to 3D dose accumulation using the 3D EQD2 calculator in RayStation v.2024B within RaySearch Laboratories' treatment planning system (3D dose). Calculated D_{max} values from each method were compared for 3 spinal cords, 2 spinal cord PRVs, 10 spinal canals, and 8 spinal canal PRVs. The data was evaluated for all spinal regions collectively and for the spinal canal and spinal canal PRV individually. In the second part of this project, the 3D dose accumulation tool was validated for cumulative volumetric dose summation in the lungs. For 10 patients, the dose from both courses of treatment was accumulated onto the previous and current patient CT scans to compare how dose summation is affected. The V_{20Gy} of the lungs was used to compare the dose summation methods as this is typically used clinically as a lung dose constraint.

Results. For spinal dose accumulation, review of previous cases uncovered errors when using the point dose method that were fortunately not to the detriment of the patient. The 3D dose method was also found to produce lower estimates for accumulated dose compared to the point dose method, with a median of the paired differences being -8.11 Gy ($p < 0.05$) and -6.39 Gy ($p > 0.05$) for the spinal canal and spinal canal PRV respectively. For accumulated volumetric lung doses, large differences were found between the dose summed onto either the current or previous CT, with a median of the paired differences of 3.35 % ($p < 0.05$).

Discussion. The dose difference seen for the spinal dose accumulation provides an opportunity to deliver more treatments with a radical intent, as 3D dose summation is less conservative, which could lead to better outcomes for patients. In the lung investigation, the large differences between the cumulative dose when summed onto the current or previous CT indicates that there are significant uncertainties associated with this pathway. However, the combined V_{20Gy} could provide quantitative information to help clinicians make better informed clinical decisions provided they are aware of the limitations of this method.

Conclusion. To conclude, this project has demonstrated the feasibility of using 3D EQD2 dose accumulation software and has highlighted the pitfalls in the current point dose method. It has also been demonstrated that this software can be used to provide accumulated volumetric dose information which may be used with caution. Finally, increasing the use of the 3D software in the department aligns the local procedure more closely with ESTRO-EORTC Consensus guidelines [2], helping to standardise this pathway.

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16 Investigating improvements in radiotherapy treatment planning and checking training to address increasing staffing pressures, workload complexity and introduction of AI

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Applied Radiotherapy, The Club Suite, October 12, 2026, 14:20 - 15:15

Background: Training in radiotherapy treatment planning is currently time and resource intensive in a clinical setting of increasing workload complexity, decreasing staffing levels relative to workload, and a time of increasing moves towards implementation of AI across the pathway. Concerns exist over building up and maintaining staff competencies in the context of a small busy radiotherapy department.

Purpose: We hypothesise that a targeted approach to training can have a positive impact. This study will investigate whether a novel training approach can provide a defensible record of training and competency; improve training quality and robustness, improve plan quality, and introduce time savings and flexibility within the team; whilst also addressing the concern that intended implementation of AI, while offering many proposed quality and efficiency savings, presents a knowledge gap and is removing the opportunity for staff to build valuable clinical experience over time.

Method: The pathway for radiotherapy plan creation and checking has been described. Site specific training programmes have been designed and delivered for prostate and palliative treatment. These trainings attempt to bring together the complete physics and planning team as well as radiographers depending on availability to encourage engagement, discussion and learning from each other. In each site-specific half day event we included relevant presentations, discussion and practical clinical examples. The training covered the planning and checking pathway as well as clinical background and physics input. A training pack is being developed as an introduction to AI in radiotherapy. A range of metrics have been defined to evaluate the impact of trainings. These include time taken to complete planning and checking tasks, time taken to achieve competency, error rates, plan quality, MU per Gray, and staff opinion on training quality. Homework tasks have been set following each training session to consolidate learning. Feedback and learning from the delivery of trainings will be used to refine the program for delivery of subsequent training events for different treatment sites.

Results: Prostate training has been delivered and was well received. Staff were enthusiastic about taking part in the event and took the opportunity to ask questions and contribute to discussions. Feedback was most positive on the clinical background which was provided by our prostate consultant radiographer, and the physics background to discrepancies in dose calculation due to prosthesis. Palliative training will take place in May with a similar format. In this event we will include clinical background again and will present on radiobiology and reirradiation as emerging themes. It has proved difficult to distinguish impact using metrics as those which rely on individuals accurately recording timings have not proved robust, the number of errors reported in the pathway is low and subject to relatively high variation, and for prostate plans specifically plan quality values show little variation in baseline data. Improving the recording of metrics is ongoing, and other plan types which show greater variation may show changes. Data collection is ongoing. Despite a lack of quantitative evidence, the training programme is considered a success so far and a valuable improvement for the team.

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Clinical Engineering succession planning and strategic workforce expansion initiatives within NHS

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Workforce, Ashes & Boundary, The Point, October 13, 2026, 09:30 - 10:30

Introduction

The rapid evolution of healthcare technologies, combined with an ageing and increasingly retiring technical workforce across the NHS, has created growing pressures on Clinical Engineering services to sustain technical capability, maintain organisational resilience, and prepare future generations of healthcare engineers [1]. These challenges are particularly significant within modern healthcare systems where patient care is increasingly dependent upon complex and continuously advancing medical device technologies. In response, the Department of Clinical Engineering based at one of the NHS trusts within Midlands, developed a strategic workforce development initiative centred on a dedicated Professional and Technical (Workforce) Development function aimed at strengthening workforce sustainability, enhancing technical competence, and supporting long-term succession planning.

Methods

The initiative adopted a workforce-focused development approach integrating technical education, competency management, apprenticeship progression, and organisational governance into a coordinated professional development framework. Central to the initiative was the expansion of a structured technical training and personal development programme designed to support staff across varying stages of technical expertise and career progression. This was supported through implementation of an in-house Technical Training Needs Analysis (Tech TNA) framework to systematically identify, review, and monitor technical competencies associated with both existing and emerging medical device technologies. In parallel, a comprehensive technical training database aligned with ISO 9001:2015 quality management system standards were developed to support oversight of training compliance, competency management, and professional development activities. Collaborative partnerships with clinical engineering section heads, universities, training providers, and medical device manufacturers enabled the development of integrated learning pathways combining in-house education, specialist technical training, competency assessment, and personalised professional development planning. The initiative additionally incorporated apprenticeship support, mentorship, careers engagement, and educational outreach activities to strengthen future workforce pipelines.

Results

The initiative strengthened organisational oversight of workforce capability through improved monitoring of staff competencies, technical training compliance, and professional development activities. The implementation of structured learning pathways enhanced opportunities for staff progression and technical skills development while supporting wider organisational objectives relating to quality assurance, governance, and patient safety. The initiative also contributed to succession planning through the development of apprenticeship [2] and mentorship pathways designed to support recruitment, retention, and progression within clinical engineering services. Furthermore, outreach and careers engagement activities increased visibility of Medical Physics and Clinical Engineering as viable healthcare career pathways. Consequently, the department has now been awarded the 'Make UK Gold Standard Kitemark' for its apprenticeship programme, further enhancing the visibility and recognition of clinical engineering services and establishing clinical engineering at the hospital / trust as a premier training department within the region.

Conclusion

Embedding a dedicated workforce development function within Clinical Engineering services represents a proactive and sustainable response to workforce transformation challenges within increasingly technology-dependent healthcare environments. This initiative demonstrates how workforce-focused innovation can strengthen organisational resilience, support technical capability development, and contribute to long-term succession planning within NHS clinical engineering services.

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18 Development of a Simple In-House Phantom for Ultrasound Uniformity QA: A Pilot Study

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Trainee, Student, Apprenticeship & Early Career Forum, 1864 Suite, October 13, 2026, 09:30 - 10:30

Background: Over time, performance of ultrasound (US) systems can deteriorate due to general wear and tear, calibration drift and transducer damage [1] [2]. Implementing quality assurance systems (QA) including objective assessment of uniformity using dedicated phantoms enables routine monitoring of US system performance. This facilitates the early detection of issues before they compromise imaging quality or diagnostic accuracy [3]. Analysis of imaging activity in England for NHS patients from April 2024 to April 2025 indicated that US represented the second most frequently performed modality [4]. Comprehensive QA programmes are a challenge to implement given the large volume of US systems across healthcare providers, the cost of commercial US QA phantoms and the complexity of US QA [5]. Our aim was to design and produce a low-cost, durable uniformity phantom which could be provided to clinical staff to perform the most objective and critical aspects of ultrasound quality assurance [3] to support the expansion of US governance across healthcare providers.

Methods: A tissue equivalent material was required to achieve the necessary speckle pattern for a B- mode uniformity phantom. Using the trust's Objet 260 Connex 3D printer, we could rapidly design and produce prototypes, with the optimal design being selected with a decision matrix. Though our initial 3D-printed phantom (fig1. a,b,c) printed with Agilus30 passed the verification steps, it did not satisfy validation as it was unable to produce sufficient scatter. This led us to develop a phantom which could be cast in 3D printed mould (fig1. d,e) using a room-temperature vulcanising (RTV) silicone (R PRO 10) and graphite powder as a scattering agent (fig1. f). Five mini phantoms were produced with different concentrations of graphite to inform the final composition (fig1. g). RTV silicone and the percentage of graphite were manually mixed and cured in plastic cups with wooden stirrers until visibly uniform. Once cured they were removed from the plastic and imaged with a B-mode scanner to assess attenuation and speed of sound (SoS) using an oversimplified method with assumptions of SoS and known distances.

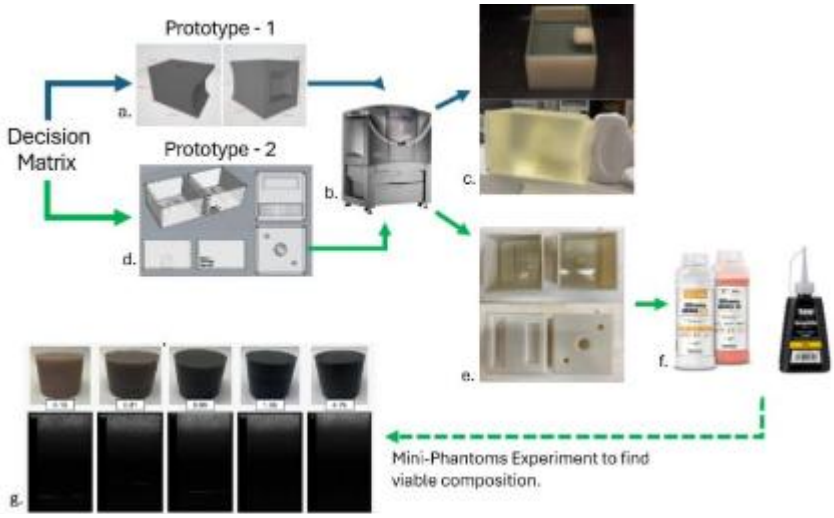


Figure 1: Workflow for our method to produce phantom designs, and mini phantoms.

Results: With increasing graphite concentrations, SoS increased whilst attenuation and uniformity remained equivalent. There was also no evidence of scattering material sinking during curing, suggesting that the RTV was sufficiently viscous. The median grey value of the phantom was highest with a percentage graphite of 1–2%, giving the brightest scatter and thus proved to be the more viable composition.

Discussion: Whilst the SoS and attenuation in the phantom differed considerably from standard tissue values, the durability of the material made it attractive for use in user QA. For QA, calibration factors should be able to account for the differences in speed and attenuation. One of the main challenges was ensuring the phantom itself was sufficiently uniform and free from air bubbles. Our manual mixing methods made it difficult to ensure repeatable uniformity between phantoms, and therefore we would recommend a mechanical mixing method is used in the future to guarantee repeatability. Whilst we had no issues with air bubbles, we also recommend utilising a vacuum chamber to properly degas the phantom. Conclusion: During this preliminary work we were able to explore a suitable method and material for production of a uniformity

phantom which can withstand use in a clinical environment. B-mode imaging results increased confidence in this method, and future work will focus on developing the final uniformity phantom using the 3D-printed mould (fig1. e), informed by clinical and technical feedback.

Acknowledgments: The authors would like to acknowledge the Mechanical Engineering Workshop for providing access to the 3D printer.

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Investigation into the use of Clarity 2D planar processing and its effects on image quality in nuclear medicine

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Trainee, Student, Apprenticeship & Early Career Forum, 1864 Suite, October 13, 2026, 09:30 - 10:30

Background: The effects of Clarity 2D processing on nuclear medicine image quality were investigated, with a particular focus on planar bone scintigraphy. Planar imaging is often limited by noise, spatial resolution, and reduced contrast, which can affect accurate lesion detection and interpretation of physiological uptake. Clarity 2D is a GE post-processing algorithm based on the Lucy-Richardson deconvolution[1] and aims to reduce image noise and increase contrast[2]. There are limited fully evaluating previous studies, but most have shown a measured increase in image contrast[3], however use similar techniques and do not explore the limitations and risks associated[4].

Method: Experiments were performed using multiple existing nuclear medicine phantoms. and a novel 3D-printed phantom. Qualitative and quantitative measurements, including contrast-to-noise ratio, spatial resolution, image count analysis, and image quality scoring, were explored.

Results: Results show that moderate blending percentages improved image sharpness, lesion delineation, and reduced image noise, which agreed with manufacturer recommendations. However, applying higher blending percentages introduced edge artefacts and compromised qualitative image quality. Uncertainties were identified due to differing results across methodologies. While quantitative measurements such as contrast to noise improved significantly at higher blending percentages, MPE & clinician image quality scoring judged these images poorer than the unprocessed reference image provided. This suggests that Clarity 2D's impact is dependent on assessment technique and input image properties.

Discussion: Low blending (below 40%), Clarity 2D provided the most balanced enhancement, improving lesion visibility and reducing noise without introducing significant artefacts. This supports the manufacturers default recommendation and suggests that modest use of Clarity 2D may provide meaningful improvements in diagnostic confidence during routine planar bone scintigraphy. In contrast, higher blending percentages produced artificial sharpening and edge artefacts, which were consistently judged to reduce diagnostic reliability despite measurable increases in contrast-to-noise ratio in phantom experiments. This work provides independent, practical evidence to support the cautious clinical implementation of Clarity 2D, demonstrating that image quality can be enhanced without additional radiation dose or scan time when appropriate blending levels are used. If the work from this investigation proves that Clarity 2D should be implemented, then patient acquisition times could be reduced leading to:

1- More patient imaging being performed in the same time frame
2- Enhanced patient experience for patients who are potentially already in pain/ struggle to lay flat & still for a prolonged period of time

Alternatively, injected activities could be reduced leading to lower patient and staff exposure, or image quality could be enhanced with the current protocol remaining unchanged. The work also highlighted the limitations of existing phantoms for assessing post-processing algorithms, as none were perfectly suited to evaluating both spatial and contrast resolution in a clinically realistic manner. The novel phantom proved most useful but would benefit from further refinement—such as incorporating smaller, closer hot spots to better challenge the limits of system resolution.

Conclusion: As the process of applying clarity 2D percentage blending creates a product of the original image with the processed image, the effects on image quality is highly dependent on the properties of the original input image. It has been useful using a range of phantoms to evaluate these effects, as varying the input image, as greatly varied the output results of what effect on image quality clarity 2D has. Conservative use of Clarity 2D may offer clinical benefits, but further clinical evaluation is required. A cohort of volunteer patients will be recruited to compare whole body bone scans with and without Clarity 2D applied requiring support from the research and development team and IRAS approval.

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Cone-Beam and Conventional CT Scanners in Dental and Maxillofacial Applications: A Quantitative Phantom Comparison

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Trainee, Student, Apprenticeship & Early Career Forum, 1864 Suite, October 13, 2026, 09:30 - 10:30

Objective:
To compare cone-beam computed tomography (CBCT) and conventional computed tomography (CT) for dental and maxillofacial imaging, with emphasis on radiation dose, image quality, reconstruction characteristics, and workflow considerations.

Methods:
A phantom-based evaluation was performed at University Hospitals Dorset using a Carestream CS 8100 3D Evo CBCT system and a Canon Aquilion Prime SP CT scanner. Clinical adult and paediatric CBCT protocols and a standard maxillofacial CT protocol were assessed using Catphan and CBCT performance phantoms. Effective dose was estimated using dose-length product (DLP) for CT and dose-area product (DAP) for CBCT with International Commission on Radiological Protection conversion factors. Image quality was evaluated using modulation transfer function (MTF) and Hounsfield unit (HU) accuracy measurements. Reconstruction approaches and workflow characteristics, including scan time and patient positioning requirements, were also compared.

Results:
The estimated effective dose for conventional CT was 717.5 µSv, compared with 107.5-165.6 µSv for CBCT, representing a four- to seven-fold dose reduction. CBCT demonstrated superior spatial resolution, with MTF50 and MTF10 values of 0.71 and 1.37 lp/mm, respectively, compared with 0.14 and 0.21 lp/mm for CT. CT demonstrated more consistent HU accuracy and remains better suited to quantitative attenuation assessment and soft-tissue evaluation. CBCT acquisitions were completed within approximately 10-40 seconds and required simpler patient positioning, whereas CT provided greater anatomical coverage and advanced iterative reconstruction capabilities.

Conclusion:
CBCT and CT provide complementary roles in dental and maxillofacial imaging. CBCT offers substantially lower radiation dose, higher spatial resolution for osseous structures, simplified workflow, and lower implementation costs, making it well suited to routine dental and implant imaging. Conventional CT remains advantageous when wider anatomical coverage, quantitative tissue characterization, or soft-tissue assessment is required. Modality selection should balance diagnostic requirements, radiation exposure, workflow efficiency, and resource considerations.

Keywords:
Cone Beam CT; conventional CT; maxillofacial imaging; dental radiology

21 Scaling stereotactic, AI auto-contouring, and adaptive radiotherapy across a large multi-centre network: aligning automation with education and competency

Mr Anthony Walsh[1]
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Implementing Innovation in Practice, Ashes & Boundary, The Point, October 13, 2026, 11:00 - 13:00

Introduction
The expansion of new technologies and techniques across global, multi-centre radiotherapy networks (over 40 departments spanning 6 geographies) requires not only robust technical solutions, but equally strong education, training, and competency frameworks. As automation and artificial intelligence (AI) tools become increasingly embedded in clinical workflows, there is a parallel need to redefine workforce skills, safeguard clinical judgement, and ensure consistent capability across geographically distributed teams.
This abstract presents the experience of a large international radiotherapy provider implementing network-wide rollouts of stereotactic capabilities, AI-enabled auto-contouring, and offline adaptive radiotherapy (offART), with a particular focus on platforms and method of training delivery, assessing and tracking competency, and ongoing credentialing.

Method
Technique development is underpinned by structured governance, competency-based credentialling, and tiered education pathways for radiation therapists, medical physicists, and clinicians. In-house training packages are developed and maintained centrally, supported by a dedicated team of subject matter experts who provide guidance, escalation, and peer review across the network using commercially available collaboration tools.

AI-driven auto-contouring has been integrated as a supervised planning support tool to improve efficiency, reduce inter-observer variability, and support protocol consistency across centres. Its deployment has been accompanied by targeted education focused on anatomical interpretation, contour review, and recognition of automation failure modes, ensuring that AI augments rather than displaces professional expertise. This has supported a shift from manual delineation toward higher-value activities including stereotactic plan evaluation, peer review, and cross-site quality assurance through structured audit.

In parallel, an offline adaptive radiotherapy (offART) workflow has been introduced to identify and manage clinically significant anatomical change during treatment. Automation assists with candidate flagging, contour propagation, and image processing, while adaptive decision-making and plan approval remain with credentialled senior staff. This model balances clinical benefit, workforce demand, and safety.

All 3 clinical roll outs mentioned in this abstract, were executed using the same training and education framework that has enabled us to release new technologies safely and efficiently at pace, whilst not compromising on quality.

Discussion
Taken together, our experience demonstrates that, when aligned with structured education and competency models, automation and AI can enable safe, scalable delivery of advanced radiotherapy techniques while supporting workforce development and resilience. Practical lessons are shared with direct relevance to UK services scaling similar capabilities across distributed networks.

22 Supporting the Safe and Effective Use of Medical Technologies in the Community

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Implementing Innovation in Practice, Ashes & Boundary, The Point, October 13, 2026, 11:00 - 13:00

Background: The use of medical technology in the community, including patients' homes, is increasing as a result of the shift of care from hospital-based pathways to community, preventative, and digitally enabled models. However, medical device governance systems remain largely designed around hospital-based environments, where equipment ownership, maintenance, training, and incident reporting are more clearly defined. In the community, responsibility for device management can fall on patients and community healthcare teams, often without consistent access to Clinical Engineering expertise. This creates risks across the device lifecycle, including device assessment and selection, training, ongoing support, maintenance, safety surveillance, asset visibility and equitable access.

Aims: This project aims to develop a MedTech Management Model to support the safe, effective and scalable use of medical technologies outside hospital settings. The work explores the future role of Clinical Engineering in enabling community-based care, including workforce development, governance structures and digital transformation.

Methods: A service-design and systems-thinking approach using the Engineering Better Care toolkit was used, informed by stakeholder engagement with patients, healthcare professionals, and strategic leaders. Workshops explored the barriers and enablers to safe community MedTech use, including training needs, device support, information accessibility, incident reporting, procurement, device tracking and clinical accountability. Findings were synthesised using thematic analysis into 10 themes covering workforce, governance, equity, training, digital support, safety surveillance and system integration.

Outputs: The proposed model combines a "MedTech Prescriber" workforce concept, a governance and safety framework, and supporting tools for those interacting with medical technology in the community. The workforce concept describes a future role for supporting technology enabled care throughout the lifecycle of medical technology. The governance framework defines responsibilities and provides guidance on implementing technology-enabled community care. The supporting tools help those interacting with medical technology in the community use them effectively and safely. One example that has been developed is MedTech Guides, a digital platform providing access to device user guides with AI-enabled chatbot support.

Impact and relevance to MPCE: This work highlights a developing future skills requirement for Clinical Engineering. As healthcare delivery shifts into the community, Clinical Engineering must adapt to provide adequate support. The model aims to ensure a proportionate level of governance and oversight is present in the community, while accounting for the unique challenges in the home and community.

Conclusion: Community-based MedTech requires more than device provision; it requires a coordinated workforce, governance and digital infrastructure to ensure technology is safe, usable and effective in real-world home and community settings. This project proposes a practical model for how Clinical Engineering can evolve to support this transition, positioning these services as key enablers of the future NHS shift from hospital-based, reactive care towards safer, preventative and digitally supported care closer to home.

23 Right to Repair for Medical Devices in the UK: A Future-Skills Agenda for Safe, Sustainable and Resilient Healthcare

Dr Victoria Kidgell, Mr Richard Stubbs, Mrs Anna Stec, Professor Laurence Kenney

Engineering Practice Deep Dive, Ashes & Boundary, The Point, October 13, 2026, 14:30 - 15:10

Background.
Right to Repair (R2R) is increasingly recognised as both a sustainability issue and a workforce capability issue for medical devices in UK healthcare. Historically, healthcare organisations have undertaken in-house maintenance and breakdown repair of equipment, supported by longstanding UK guidance on managing medical devices [1]. However, some organisations have experienced increasing restrictions on access to parts, service information, software, tools and training [2–5]. At the same time, wider UK and European debates on product safety, eco-design, repairability and circular economy have increased interest in repair as a route to resilience and carbon reduction [4,6–8]. In response, a multidisciplinary working group was established in 2024 and published a 2025 position statement on R2R. Beyond sustainability and resilience, this work raises important questions about the future skills required of the medical physics and clinical engineering (MPCE) workforce, including repair competence, software-enabled diagnostics, procurement literacy, standards interpretation and cross-sector leadership.

Methods.
The work combined: (1) member consultation; (2) formation of a multidisciplinary working group including clinical engineering, medical physics, rehabilitation engineering, academia and industry; (3) review of relevant policy and regulatory context; (4) development of a formal position statement; and (5) early implementation discussions with national stakeholders. Practical examples from clinical engineering services were also reviewed to identify recurring barriers and enablers to local repair.

Results.
The position statement identified several potential benefits of a well-structured R2R framework: faster repair, reduced service and maintenance costs, improved equipment availability, lower transport-related emissions, and stronger contribution to social value objectives [2]. Key implementation requirements included access to genuine parts, software and technical information; standardised repair protocols; clear liability and accountability arrangements; training and certification; and alignment with national standards and regulatory requirements, including preservation of CE/UKCA conformity [2]. Practical examples highlighted recurring barriers including restricted access to service tools and software, limited technical training, supplier refusal to sell parts, high-cost service models, long repair lead times, and increasing dependence on modular replacement rather than component-level repair. These issues affect not only cost and sustainability, but also the capabilities expected of the future engineering workforce.

Discussion.
R2R sits at the intersection of sustainability, safety, procurement, regulation and workforce development. The work to date suggests that the most pragmatic near-term opportunity lies in procurement — for example, clarifying expectations around service documentation, software support, spare parts, training, tools and through-life maintenance responsibilities at the point of purchase. R2R should also be understood as a future-skills agenda for the MPCE workforce, requiring stronger capability in digital troubleshooting, standards interpretation, supplier engagement, whole-life costing, sustainable procurement and system leadership. The next phase of the work will require closer collaboration with policy-makers, procurement leaders and industry to clarify expectations, develop practical models, and inform future regulatory and procurement approaches.

Conclusion.
R2R offers a route to improve sustainability, affordability and resilience in healthcare while maintaining safety and compliance. The next phase should focus not only on policy and procurement tools, but also on defining the competencies, training pathways and leadership capabilities needed to support safe and sustainable repair practice in the future MPCE workforce.

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The impact of regional practice educators in Clinical Engineering

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Engineering Practice Deep Dive, Ashes & Boundary, The Point, October 13, 2026, 14:30 - 15:10

Background: An aging technical workforce in Clinical Engineering, together with an increasing gap in practical skills for graduates joining the workforce, has resulted in difficulties recruiting individuals with the correct skill mix to meet the current and future demands for the role. From 2023, regional NHS Clinical Engineering practice educators and project leads in London, the South East and East of England were funded via different routes including NHS England, and the South East Imaging Training Academy to support increasing training capacity in Clinical Engineering. Despite the funding being time limited and regionally variable, resources have been pooled and work co-ordinated for the benefit of the profession.

Methods: The Clinical Engineering practice educators each have different remits and work to regionally defined objectives and budgets. However, by collaborating across regions some shared resources and opportunities have been developed to improve training available to all Clinical Engineering staff regardless of region.

Results: Our presentation will focus on the learning taken from developing some of these resources and how the model could be adapted elsewhere.
Examples of the collective outputs of the regional Clinical Engineering practice educator work are discussed. These arose from identification of gaps from communities of practice and management meetings.

Discussion:
Sharing resources and outputs across regions helps to avoid duplication. By being a safe space, educators can share ideas with peers and work creatively, which is essential to make these roles effective. It opens opportunities for further CPD activities as the field develops, in areas such as device integration and networking, ensuring that our professional training needs are met as we move forward with the NHS 10-year plan.
Northern England and Wales have not allocated funding specifically for Practice Educators but work on a more consortium-based approach across a variety of training centres. Educators involved in these approaches are invited to feed into this network to ensure that learning can be shared effectively nationally.

Conclusion: To meet the workforce challenges in Clinical Engineering, we must support all training routes and levels. Practice educators provide support and expertise across their regional footprint. By collaborating, we can extend this impact to a national level.

25 From “I Hope This Works” to “I Know This Works”: Confidence Through Medical Physics Simulation

Mrs Frances Bird, Dr Harry Poole, Matthew Gardner, Amy Collis, Dominika Wojdylo, Katherine Chase

Medical Physics, 1864 Suite, October 13, 2026, 14:30 - 15:10

Background. Simulation based training has become a critical component of medical training yet is rarely used to its fullest for Medical Physics. Simulation offers a safe, reproducible environment for practising complex tasks without risk to patients. Final year trainees may find the transition into a qualified role daunting; simulation provides an opportunity to explore their behaviours, assess their current knowledge level, and reflect on their actions.

Previous work has demonstrated improvements in skill acquisition, error reduction, and trainee confidence through simulation [1,2,3].

Methods. 26 medical physics final year trainees were invited to take part in this simulation pilot scheme. Simulation scenarios were performed for all specialisms of medical physics with each session focusing on one specialism (Radiotherapy, Radiation Safety and Diagnostic Radiology, Nuclear Medicine or Imaging with Non-Ionising Radiation). Simulations lasted up to 15 minutes and a debrief followed straight afterwards. Trainees were asked to reflect on the simulations and share learning with the group. Trainees were asked to complete a pre- and post-session survey.

Results. Table 1 shows an increase in trainee confidence across a number of areas following the simulations sessions.

How confident do you feel …	% Change
…that my clinical knowledge is appropriate for my level	+23
...that I practice within the limitations of my level	+19
… that I possess sufficient strategies to raise concerns when necessary	+17
… that I possess skills and knowledge to communicate with a patient	+31
…that I possess the skills required to communicate information to the rest of an MDT	+21
… that I possess the skills required cope with difficult or challenging communications	+20

Table 1: The percentage change in responses between the surveys.

Discussion. The findings demonstrate that simulation-based training provided measurable benefits to confidence for Medical Physics trainees. The structured, low-risk environment allowed participants to practise scenarios and reflect on their actions. This opportunity helps to bridge the gap between working as a trainee and working as a qualified Clinical Scientist. These results align with broader literature supporting simulation as a high-value educational strategy in healthcare professions.

Conclusion. A structured Medical Physics simulation-training programme significantly improved trainee confidence. Simulation should be considered a highly beneficial component of modern Medical Physics education, complementing clinical placements and supporting the development of safe, competent Clinical Scientists in the run up to qualification.

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26 Speed-Running the STP: How Accelerating First-Year Rotations Improves Trainee Engagement and Experience

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Medical Physics, 1864 Suite, October 13, 2026, 14:30 - 15:10

The Problem: Following the introduction of the updated STP curriculum in 2022, first-year rotational training was organised into four eight-week blocks. This was intended to allow trainees to complete required competencies alongside academic commitments, while gaining experience across all specialisms before progressing to year two.

In practice, this structure presented a number of challenges. Some trainees approached their final examinations without exposure to at least one specialism, and in some cases were required to complete coursework before undertaking the relevant clinical placement. This led to a sense of being underprepared for both academic work and assessments.

Frequent adjustments to rotation schedules, often due to annual leave, also created difficulties for departments in planning teaching and supervision. As a result, both trainees and training leads experienced a lack of consistency across the year.

The Solution: A revised training timeline was introduced to better align clinical placements with academic requirements while improving consistency for departments. The key changes were:

- A three-week introductory period, during which trainees spent half a week in each specialism. This included a collaborative presentation addressing the "Shadow a Clinical Scientist…" activity.
- Six-week rotational blocks, designed to be focused and achievable within the available time and alignment with academic placements, to minimise disruption to rotations.
- An eight-week catch-up period following examinations, allowing trainees to complete outstanding competencies based on individual needs, with a more trainee-led approach.

The Benefits: The revised structure improved alignment with coursework delivered by the academic centre, allowing trainees to draw on clinical experience to support their academic work. Early exposure to all specialisms meant that trainees had some familiarity with each area before their examinations, which improved confidence and perceived preparedness.

Most trainees were able to complete the majority, and in many cases all, of their required competencies within the six-week rotations. This enabled an earlier transition into specialism-focused training. The introductory period also allowed several training activities to be completed in advance, reducing the assessment burden later in the year.

Feedback indicated that the initial shadowing period was particularly valuable in building confidence ahead of academic placements. Although trainees described the shorter rotations as busy, they did not feel overwhelmed. From a departmental perspective, a more stable schedule made it easier to plan teaching and supervision.

The Future Plans:

Further refinements are planned to build on the current structure. These include introducing structured pre-rotation preparation, such as short introductory materials for each specialism, to help trainees make better use of time within placements. In addition, midpoint check-ins within each rotation will be trialled to identify gaps in competencies earlier and allow more timely support.

We also aim to start trainees earlier in the training year to allow a more in-depth introductory period, with the potential to incorporate additional competencies such as "Attend a meeting…" activities within this phase.

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Nuclear Medicine Band 3 Training Programme

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Technologists, The Club Suite, October 13, 2026, 14:30 - 15:10

Background:
Nuclear Medicine services across the UK continue to face persistent **workforce shortages**, **limited training pipelines**, and **increasing service pressures**.
In response to these pressures, a Nuclear Medicine department within a district general hospital developed a locally deliverable Band 3 training programme to **strengthen workforce capability** while **maintaining regulatory and scientific standards**.
The initiative originated from a Band 3 assistant seeking progression opportunities despite lacking access to established pathways such as the Band 4 Assistant Practitioner route.

Methods:
The programme was co-designed by the Lead Radiographer and Lead Clinical Scientist, with input from the London Imaging Academy and Nuclear Medicine Practice Educators. It provides a structured, competency-based pathway mapped explicitly to Band 3 scope of practice and aligned with IR(ME)R 2017, IRR 2017, EPR 2016, ARSAC guidance, and BNMS recommendations. Training is delivered through modular theoretical teaching, simulation, supervised clinical practice, and governance-driven assessment, ensuring safe integration of Band 3 staff into defined elements of the Nuclear Medicine workflow.

Results:
A pilot cohort of two trainees (2025–2026) is being evaluated using a multi-metric framework capturing competence, confidence, service impact, equity of access, and inspection readiness. Early outcomes indicate improved service resilience, reduced operational delays, enhanced staff engagement, and positive feedback during external inspection. The model also establishes a structured internal pipeline toward Band 4 and Band 5 roles, supporting long-term workforce sustainability.

Conclusion:
This work demonstrates a practical, safety-focused approach to expanding Nuclear Medicine workforce capacity through local training innovation. It offers a scalable template for departments seeking to address workforce shortages while upholding the scientific, regulatory, and quality standards central to IPEM's mission.
The model offers a scalable, adaptable approach that may support national efforts to modernise and stabilise the Nuclear Medicine workforce.

Key references:

(1) Increasing Service pressures, (2) Limited training pipelines, (3) Maintaining regulatory and scientific standards, (4) Strengthen workforce capacity, (5) Workforce shortages