IPEM conferences

Quality Assurance in MRI

29th April 2021- Online

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10:10 - 10:45	**QA for Advanced Neuro MRI Techniques in the Clinic** Dr Donald McRobbie, Associate Professor, University of Adelaide
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11.24 – 11.36	**Quality Assurance in MRI for Radiotherapy Planning – Recommendations from an IPEM working party on the use of MRI for external beam Radiotherapy Planning** Richard Speight, Leeds Cancer Centre.
11.36 – 11.48	**Developing quality assurance tests for PET-MR imaging for radiotherapy planning** Jonathan Wyatt, Translational and Clinical Research Institute, Newcastle University,
11.48 – 12.00	**Monthly Quantitative Diffusion QA Using the HPD Diffusion Phantom on a MR-Linac** Chris Moore, The Christie NHS Foundation Trust, Manchester
12.00 – 12.12	**Metrology, Traceability and Quantitative MRI** Matt G Hall, National Physical Laboratory, Teddington
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14.35 – 15.10	**Accreditation of the MRI Physics Service in the UK** Dr Peter Jarritt, Chair of the UKAS MPACE Technical Advisory Committee. Dr David Compton, UKAS
15.10 - 15.22	**Quality assurance of breast MRI as part of the surveillance of women at higher risk in the UK** Dan Wilson, The Leeds Teaching Hospitals NHS Trust, UK
15.22 – 15.34	**Hazen: A free, open-source library for MRI QA analysis** Haris Shuaib, Guy's & St Thomas' NHS Foundation Trust, London
15.34 – 15.46	**Big Data QA: Monitoring MRI Performance Through Clinical Images** Jonathan Ashmore, Inverness, NHS Highland.
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Organised by IPEM's Magnetic Resonance Special Interest Group

Please see below for the Invited Speaker biographies and abstracts for all Oral talks.

Experience in Setting up a National QA programme in Finland
Dr Juha L Peltonen, Helsinki University Hospital Medical.

Juha Peltonen has been working as a Medical Physicist in University of Helsinki´s Medical Imaging Center (Finland) since 2009. His professional and research interests are specifically on medical image processing, artificial intelligence, quality assurance (QA) in radiology and magnetic resonance imaging (MRI). Dr Peltonen got his DSc (Tech) from Aalto University (Helsinki, Finland) in 2018 with research focusing on QA of MRI, especially using clinical images for QA and computational processing methods related to QA image analysis. His earlier studies include magnetic field theory and biomedical engineering in Aalto University, Helsinki ja TU Delft, The Netherlands.
He is also working as a radiation protection adviser and medical physics expert in the HUS Medical Imaging Center.
Dr Peltonen is the president of the medical physicist detachment in the Finnish Radiological Society.

Abstract
The public healthcare system in Finland is consisting of 20 hospital districts assigned under 5 university hospitals and serving in total 5.5 million inhabitants. With additional private healthcare companies, the density of MRI devices is relatively high: 26 scanners per million inhabitants. As in most of the European countries, the regulation of MRI practices is almost non-existent, including quality assurance (QA). However, running a QA protocol is well-motivated to guarantee the accuracy of imaging studies.

In 2017 the medical physicist detachment of the Finnish Radiological Society carried out a survey to find out what kind of QA programs are in place among different service providers and to see if an effort to produce national best-practice guideline for MRI guideline is needed. In the survey it was found that applied QA protocols vary in terms of what measurements are being done, who is doing the measurements and what kind of test objects are being used. However, it was a common consensus that the impact of various measurements is not clear and a unified guideline for recommended test protocol would be greatly welcomed. Responders also felt that a national QA guideline would help them to justify required work and device hours similar to the regulated ionizing radiation QA protocols. Thus, the workgroup to produce national MRI QA guideline was formed. The guideline is consisting of five parts: 1) Recommended measurement program 2) Recommended test objects 3) Recommended measurement method for each step in the program 4) Additional suitable tests 5) Applicable computational methods. Currently, the recommended test program has been agreed on and major part of the actual writing has been done. The preliminary draft of the guideline is going to be handed out to circulation for comments later in 2021.

The number of MRI devices and the complexity of studies is growing constantly requiring increasing amount of medical physics experts´ time. Thus, the last chapter of the guideline is covering computational methods to automate QA measurement analysis processes and release time from analysis to interpretation. These methods include image analysis tools to quantify annual phantom measurements and examples how to build a daily or weekly phantom image analysis pipeline. Additionally, using clinical images to follow image quality is proposed.

QA for Advanced Neuro MRI Techniques in the Clinic
Dr Donald McRobbie, Associate Professor, University of Adelaide

Donald McRobbie grew up in Aberdeen, Scotland. He has a BSc in Physics (1980) and an MSc in Medical Physics (1981) from the University of Aberdeen and a PhD from the University of London (1990). His first research post was in Aberdeen investigating the biological effects of magnetic fields. He moved to the Royal Postgraduate Medical School, London in 1984, transferring to Imperial College in 1988. From 1990 he was at Charing Cross Hospital as principal physicist, then Deputy Director and later Director of the Radiological Sciences Unit, Imperial College Healthcare NHS Trust and honorary Senior Lecturer in the Departments of Imaging Science and Surgery. He was a scientific and radiation safety advisor to the London 2012 Olympics.

In 2013 he moved to Australia to be Chief Physicist at Flinders Medical Centre in Adelaide, before becoming the Director of Medical Physics and Radiation Safety for the South Australian public health service. He was awarded a Distinguished Talent Visa by the Australian Department Immigration and Border Protection in May 2014 for his professional and research contributions to medical physics and MRI. Presently he is a freelance MRI educator and Adjunct Associate Professor at the University of Adelaide presenting courses in MR physics and MR safety throughout Australia and New Zealand, in Dubai and, with Eden Learning in the UK. In 2020 he developed the world's first complete MR Safety Expert training course and certification scheme for the Australasian College of Physical Scientists and Engineers in Medicine (ACPSEM).

He is a co-author of the popular MR physics textbook MRI from Picture to Proton and sole author of Essentials of MRI Safety published in 2020. His research interests lie mainly in the areas of advanced neurological MRI applications, the biological effects of magnetic fields, MR safety, and radiation dosimetry in CT. In another life, he is a blogger (www.drdinoz.com), aspiring novelist, and a blues-rock artist (Doctor D).

Abstract

The translation of advanced MRI techniques from the research arena into clinical practice requires a robust approach to quality assurance. There are several inherent differences between research applications and their use in clinical diagnostic imaging. These include the application of the methodology to individual patients as opposed to groups of subjects where individual differences and minor mis-calibrations may be averaged out, the need for a high level of confidence in the results because their interpretation will affect decisions on patient management, in addition to the procedural and ethical issues associated with investigations which may be in the "off-label" domain. A further issue is the performance requirement placed on the MRI equipment for examinations such as BOLD (Blood Oxygenation Level Dependent) fMRI, and high b-value, high angular resolution diffusion-weighted imaging (HARDI). Another complicating factor is that the desired physiological or anatomical 'signal' may be dynamic as in fMRI or physically complex as in MR tractography, and therefore hard to replicate in a phantom or test object.

Sources which affect variability and quality in fMRI include scanner-based parameters which can be assessed using phantoms: signal-to-noise ratio, stability, and Fourier analysis of fluctuations[1]. However the greatest sources of uncertainty arise from the patient: movement, stimulus-correlated or otherwise, and which may affect the local magnetic field and the T2* signal changes responsible for the BOLD signal, itself only a few percent of the MR signal. A more fundamental issue with clinical fMRI, particularly for non-motor-cortex paradigms is the level of engagement by the patient to the tasks presented.

In diffusion imaging suitable phantom materials include alkanes, gels and aqueous solutions[2] but these are essentially isotropic in nature. The anisotropy and complexity of white matter organisation in the brain, as well as the methodological limitations of the MR techniques used to probe them, present a further level of complexity for QA. The use of test datasets can investigate the relative sensitivities of different methodologies[3] but is unhelpful for the individual patient.

In both clinical fMRI and tractography QA can be based upon the patient's scans themselves. A QC regime for tractography using the constrained spherical convolution MRtrix software has been developed and trialled at Flinders Medical Centre and the University of Adelaide[4]. Investigation of the effects of image noise and movement has established simple QA parameter limits[5] that can provide the clinician with an appropriate level of confidence in the diagnostic values of the tractograms, resulting in beneficial outcomes for patients.

[1] Weisskoff RM (1996). Simple measurement of scanner stability for functional NMR imaging of activation in the brain. Magn. Reson.Med. 36: 643-654.

[2] Lavdas I, Behan K, Papadaki A, et al. (2013) A phantom for diffusion weighted magnetic resonance imaging (DW-MRI)', J. Magn. Reson. Imag. 38: 173-179.

[3] Thomas C, Ye FQ, Irfanoglu MO et al. (2014). Anatomical accuracy of bran connections derived from diffusion MRI tractography is inherently limited. PNAS 111:44: 16574-16579.

[4] McRobbie DW, Agzarian M (2016). Quality Control measures for Constrained Spherical Deconvolution MR diffusion tractography in clinical use. Proc. Intl. Soc. Mag. Reson. Med. 24.

[5] Lannan O, Santos A, McRobbie D (2018) Validation of the MRtrix tractography software for clinical use. Engineering and Physical Sciences in Medicine, 26-30 October 2018, Adelaide.

Assessing and addressing the repeatability of Magnetic Resonance Fingerprinting T1/T2 measures for clinical standardisation of quantitative MR.

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**Contributed equally to this work*

Background. Magnetic Resonance Fingerprinting (MRF) is able to rapidly measure multiple quantitative features through a single acquisition. The sequence is available on clinical scanners to measure T1 and T2 quantitatively. The aim of this study was to assess the repeatability of MRF T1 and T2 measures in the ISMRM/NIST system phantom and healthy volunteers and compare these to T1 and T2 measures obtained using standard protocols.

Methods. The ISMRM/NIST system phantom and 10 healthy volunteers were scanned on a 3T Magnetom Prisma Scanner (Siemens Healthcare, Germany). The protocol included a 2D multi-echo spin echo (MESE) for T2 measurements, a 3D VIBE sequence for variable flip angle (VFA) T1 measurements and two MRF repeats, described in (1) and (2). Measurements at different temperatures were taken for the phantom. A correlation between standard and MRF methods was performed and Bland Altman analysis carried out.

Results. Spearman's Rho correlation showed a strong significant correlation between MRF and standard T1/T2 measures. In the phantom study, a mean bias of 113ms (9.2%) was observed between MRF T1 and VFA T1 and 13ms (2.2%) between MRF T2 and MESE T2. In healthy volunteers a mean bias of 262.5ms (19.5%) was observed between MRF T1 and VFA T1, and 26.7ms (41.6%) between MRF T2 and MESE T2. MRF T1 and T2 measures in healthy volunteers were found to be strongly repeatable with a mean bias of 1.2ms (0.1%) for T1, and 0.2ms (0.3%) for T2.

Discussion. MRF was shown to be strongly repeatable and to rapidly quantify T1 and T2, with a 7 min sequence for whole brain, compared to 12 min for the faster available standard methods. A number of methods for measuring T1 and T2 exist and the analyses and results highlighted the importance of defining gold standards. T1 and T2 measures in the phantom, needed temperature correction and discussion with the manufacturer around discrepancies. In healthy volunteers, comparisons to previous studies highlighted the differences in image analysis methodologies, which can lead to large variations in measurements. Furthermore, other factors, such as magnetisation transfer need to be taken into account in future work (3).

Conclusion. Within this study MRF was found to be strongly repeatable. A bias was present between MRF and standard measures of T1 and T2. However, current challenges around the clinical standardisation process, particularly in relation to defining gold standards through phantom design, image acquisition and image analyses need to be addressed.

Key references.

(1) Smith et al, Validity and reproducibility of Magnetic Resonance Fingerprinting in the healthy human brain at 3T. ISMRM 2020.
(2) Statton et al, Accuracy, reproducibility and temperature variability of Magnetic Resonance Fingerprinting using the ISMRM/NIST system phantom. ISMRM 2020.
(3) Texeira et al, Controlled saturation magnetization transfer for reproducible multivendor variable flip angle T1 and T2 mapping. MRM. 2020.

Acknowledgements:

The authors would like to thank the volunteers who participated in the study; Funding from the Imperial CRUK Centre and the Imperial NHS Imaging Department; the Imperial NHS ImRes Group; the Imperial MRI Physics Collective; Iulius Dragonu and Mathias Nittka, Siemens Healthineers, UK and Germany. MGS is part funded by the National Physics Laboratory's ISCF Medical Imaging Accelerator programme financed by the Department for Business, Energy and Industrial Strategy's Industrial Strategy Challenge Fund.

Quality Assurance in MRI for Radiotherapy Planning – Recommendations from an IPEM working party on the use of MRI for external beam Radiotherapy Planning

Richard Speight[1], Michael Dubec[2], Cynthia L Eccles[2], Ben George[3], Ann Henry[1], Trina Herbert[4], Robert I Johnstone[5], Gary P Liney[6], Hazel McCallum[7], Maria A Schmidt[4]

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Purpose/Objective

The use of MR in external beam radiotherapy (RT) planning is growing. The literature shows significant heterogeneity in the way that MR for RT is implemented and there is some evidence that this is, in part, due to a lack of consensus in the literature and guidance from professional bodies [1-2]. To combat this, The Institute of Physics and Engineering in Medicine (IPEM) commissioned a working party to produce a guidance document on the use of MR for RT treatment planning. This multi-disciplinary group includes Clinical Scientists in MRI and RT, Radiographers and an Oncologist. The recently published guidance was endorsed by the IPEM, the Royal College of Radiologists and the Society of Radiographers [3]; key recommendations on Quality Assurance are presented in this abstract.

Material/Methods

The guidance produced by the working party is based on the experience of the institutions represented, in consultation with other institutions, as well as on information taken from the literature (2018-2020). Quality Assurance guidance is given for MRI acquired for external beam RT treatment planning in workflows based on CT-MR fusion, i.e. when MRI is acquired and registered to CT with the purpose of aiding delineation of target or organ at risk volumes. MRI used for treatment response assessment, MRI-only RT and other RT treatment types such as brachytherapy, gamma radiosurgery and MR-Linac are not within the scope of this document.

Results

The guidelines were designed as a practical document. In MRI Quality Assurance, recommendations comprise standard MR image quality tests [4], standard testing of RT features (couch, lasers) [5] and additional testing of MR aspects particularly relevant to the RT planning workload: patient communication, DICOM header checks, geometric distortion checks and end-to-end checks. Geometric distortion associated with both hardware and susceptibility effects are considered, and so is the presence of RT accessories. Recommendations on testing frequency also cover Acceptance Testing and Commissioning. The report also makes recommendations for the design of MR sequences for RT planning, minimising geometric distortion. Despite highlighting shortcomings of the use of images acquired for diagnostic purposes in RT planning, the guidance provides a basic checklist for consideration in individual cases. The report also makes recommendations on commissioning and per-patient verification tests for CT-MR registration.

Conclusion

The IPEM guidance document is comprehensive and addresses many aspects of the use of MRI in RT planning, including Quality Assurance. This document is expected to contribute to the safe implementation of MRI for external beam radiotherapy both for centres with dedicated MR scanners for RT and for centres where MR for RT planning is a small part of the most often diagnostic workload. The level of MR expertise in RT centres is known to vary, and it is hoped that this document will contribute to standardisation and harmonisation of quality assurance processes.

References

[1] - Speight et al. IPEM Topical Report: A 2018 IPEM audit of MRI use for external beam radiotherapy treatment planning in the UK, PMB, (2019) https://doi.org/10.1088/1361-6560/ab2c7c

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[3] - Speight et al. IPEM topical report: Guidance on the use of MRI for external beam radiotherapy treatment planning, PMB, (2021) https://doi.org/10.1088/1361-6560/abdc30

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Developing quality assurance tests for PET-MR imaging for radiotherapy planning

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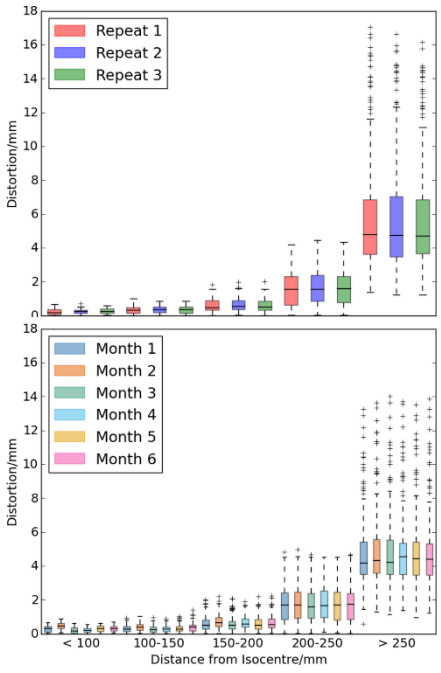
Background. Simultaneous Positron Emission Tomography – Magnetic Resonance (PET-MR) imaging enables acquiring MR anatomical and functional information and PET molecular information with high degrees of spatial alignment.[1] This has great potential to improve radiotherapy by identifying tumour sub-volumes to receive 'boost' radiation doses,[2] potentially increasing tumour control.[3] To use PET-MR imaging for radiotherapy planning requires Quality Assurance (QA) tests to be developed, tailored to radiotherapy purposes. This study aimed to develop these tests programme and assess their repeatability and longitudinal stability.

Methods. The QA tests developed were: 1) electromechanical accuracy, 2) MR image quality, 3) MR geometric distortion, 4) PET-MR alignment accuracy, 5) PET Standard Uptake Value (SUV) accuracy and 6) diffusion weighted (DW)-MR Apparent Diffusion Coefficient (ADC) accuracy. Each test used a dedicated phantom: 1) Aquarius MRI phantom, 2) American College of Radiologists large image quality phantom, 3) GRADE phantom, 4) VQC phantom, 5) in-house uniform PET activity phantom and 6) in-house phantom with vials containing n-nonane, n-undecane and tridecane, immersed in water. Each test was analysed automatically or semi-automatically, using in-house developed software. The repeatability of each test was evaluated by acquiring three separate measurements with independent phantom positions on the same day. The longitudinal stability was assessed through making monthly measurements over 6 months. All measurements were carried out on a Signa 3T PET-MR scanner.

Results. MR geometric distortion results in the figure. All other results are given in the table.



Test	Component	Repeatability		Monthly Stability	
		Mean	*SD*	*Mean*	*SD*
1) Electro-mechanical Accuracy	External Laser Right-Left Offset	0.1 mm	0.3 mm	0.4 mm	0.4 mm
	External Laser Ant-Post Offset	0.0 mm	0.3 mm	0.5 mm	0.1 mm
	External Laser Pitch Angle	-0.1^o	0.1^o	-0.2^o	0.1^o
	External Laser Roll Angle	0.2^o	0.2^o	0.1^o	0.1^o
	External Laser Yaw Angle	-0.1^o	0.1^o	-0.1^o	0.1^o
	External Laser Lateral Coincidence	0.0 mm	0.0 mm	0.0 mm	0.0 mm
	External Laser Movements	0.0 mm	0.1 mm	0.1 mm	0.1 mm
	External - Internal Laser Right-left Difference	1.7 mm	0.3 mm	1.8 mm	0.3 mm
	Internal Laser Sup-Inf Offset	2.2 mm	0.6 mm	1.4 mm	0.5 mm
	Couch Movements	0.1 mm	0.5 mm	0.5 mm	0.4 mm
2) MR Image Quality	Spatial Resolution (T1)	1.0 mm	0.0 mm	1.0 mm	0.0 mm
	Spatial Resolution (T2)	1.0 mm	0.0 mm	1.0 mm	0.0 mm
	Slice Thickness (T1)	5.3 mm	0.2 mm	5.5 mm	0.4 mm
	Slice Thickness (T2)	4.9 mm	0.2 mm	5.2 mm	0.4 mm
	Slice Position (T1)	1.3 mm	0.6 mm	0.8 mm	1.9 mm
	Slice Position (T2)	1.4 mm	0.5 mm	0.6 mm	2.0 mm
	Image Uniformity (T1)	88.8 %	0.3 %	89.4 %	0.6 %
	Image Uniformity (T2)	85.0 %	0.1 %	83.6 %	1.2 %
	Ghosting (T1)	0.7×10^{-2} %	0.05×10^{-2} %	1.3×10^{-2} %	0.3×10^{-2} %
	Ghosting (T2)	0.9×10^{-2} %	0.04×10^{-2} %	2.5×10^{-2} %	0.8×10^{-2} %
	Low-Contrast Detectability (T1)	35	1	33	2
	Low-Contrast Detectability (T2)	26	1	22	1
4) PET-MR Alignment	Right-Left Difference	0.15 mm	0.03 mm	−0.3 mm	0.1 mm
	Ant-Post Difference	0.12 mm	0.02 mm	0.0 mm	0.1 mm
	Sup-Inf Difference	0.02 mm	0.07 mm	0.1 mm	0.2 mm
	Pitch Angle	0.13^o	0.07^o	0.0^o	0.1^o
	Roll Angle	-0.01^o	0.00^o	0.04^o	0.05^o
	Yaw Angle	0.01^o	0.05^o	-0.07^o	0.06^o
5) PET SUV Accuracy	SUV Difference	1.3%	0.5%	1.1%	2.5%
6) DW-MR ADC Accuracy	Nonane Difference	2%	1%	4%	2%
	Undecane Difference	−2%	2%	1%	2%
	Tridecane Difference	−2%	3%	4%	6%

Discussion. The repeatability and stability of the MR geometric distortion tests appeared high, with the distribution of distortions within different distances from the isocentre being similar between repeats and over time (figure 1). The repeatability of all other tests also appeared high, with low Standard Deviations (SDs, table). The electromechanical and some MR image quality tests had similar monthly and same-day repeat SDs. However most tests had larger monthly than repeatability SDs. All tests had no observable trends and monthly means agreeing with repeatability means within two SDs (except for two which agreed within four SD).

Conclusion. QA tests for radiotherapy planning PET-MR have been developed. The tests appeared repeatable and stable over a six-month period, although monthly variation was larger than test repeatability for most tests. Implementing these QA tests will enable high-quality, robust PET-MR imaging to be used for radiotherapy planning.

Key references. [3]J. M. Galvin, W. De Neve, J Clin Oncol 25 2007.

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Monthly Quantitative Diffusion QA Using the HPD Diffusion Phantom on a MR-Linac

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Background. The magnetic resonance linear accelerator (MRL) is the next step in image guided radiotherapy offering superior soft tissue contrast, when compared to CT, and daily imaging (1). There is interest in developing functional imaging, such as diffusion weighted imaging (DWI) for use on the MRL (2). Due to the reduced gradient specifications compared to diagnostic scanners, non-standard b-values must be used for DWI on the so that measured apparent diffusion coefficient (ADC) values are comparable between the MRL and diagnostic systems (3). A monthly QA programme has been developed to test the accuracy and repeatability of the ADC maps estimated using the DWI sequence developed by the Elekta MRL biomarkers working group (3). The sequences were tested on the HPD diffusion ice-water phantom, (4) which contains 13 vials, with a range of ADC values calibrated at 0.0 ± 0.2 ^{o}C.

Methods. The HPD phantom was imaged for three consecutive months on a 1.5 T Elekta Unity MRL using a prostate DWI sequence recommended by the working group (2D SS-EPI, TR/TE = 3354/83, Matrix = 108x108, 17 slices, b-values = 0, 150, 500 s/mm^2) with the linear accelerator gantry stationary at 0^{o}, 90^{o}, 180^{o}, 270^{o} and 360^{o}, retaining the shimming from the gantry angle 0^{o} scan to emulate the effects of imaging after moving the gantry for treatment (5). DW images were also acquired while moving the gantry during the imaging sequence to simulate an intensity modulated radiotherapy (IMRT) plan. The temperature of the ice-water bath surrounding the vials was measured before and after imaging. ADC maps (fig. 1) were calculated from the log of the signal from pairs of b-value images with b = 150, 500 s/mm^2. Accuracy was assessed by comparing region of interest mean ADC values with manufacturer-supplied reference values using Bland-Altman analysis, and repeatability was assessed with a coefficient of variation (CoV) between the measurements over the three months.

Results. Fig. 2 shows a Bland-Altman plot of percentage difference between measured mean ADC and true values for the IMRT simulation sequence. Each marker denotes a vial ADC measurement. There is a mean difference of 2.6 % with LoA of -5% and 10%, although these are heavily skewed by the low ADC measurements. Fig. 3 shows the repeatability of the same sequence with CoV <0.1 for all measured ADC values, improving as ADC increases.

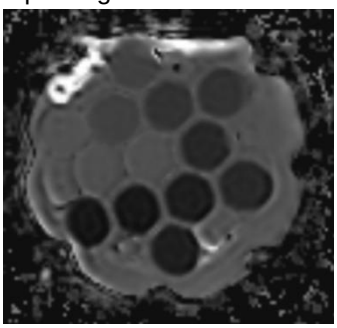

Fig.1: ADC Map of Phantom

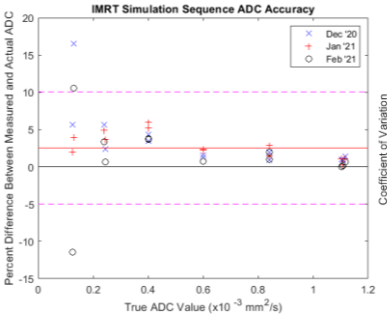

Fig.2: Accuracy

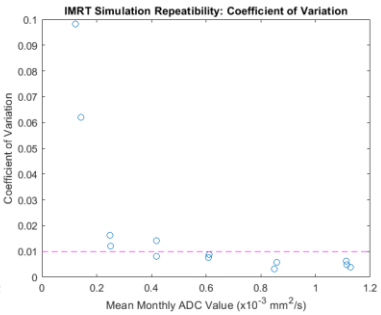

Fig.3: Repeatibility

Discussion. The MRL Biomarkers sequence produces accurate and repeatable mean ADC maps using the b 150 and 500 s/mm^2 images. Gantry angle or gantry rotation during image acquisition had no significant effect on measured ADC. These phantom measurements do not consider the effects of perfusion on clinical ADC measurements. More monthly images should be acquired to confirm the initial findings. These metrics are excellent for clinical ADC values (ADC >0.5 x10^{-3} mm^2/s) (6) .

Conclusion. The DWI sequence tested for the prostate produces accurate and repeatable ADC values in a phantom, giving confidence clinical ADC measurements will be similarly accurate.

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Metrology, Traceability and Quantitative MRI

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Introduction

The emergence of quantitative methods in MRI places new and more stringent requirements on quality assurance for MRI facilities. MRI can be used to measure a variety of quantities. Measurements of a physical property are very different to conventional, relative contrast - their values can be independently verified and benchmarked. This presents a unique opportunity to improve scanner calibration and QA, and to quantify the differences between systems. Unlike scanner-dependent signals, measurements of physical quantities can be tested and characterised for bias and uncertainty, and the differences between different techniques and scanners robustly quantified [1]. This is the domain of metrology, the science of measurement.

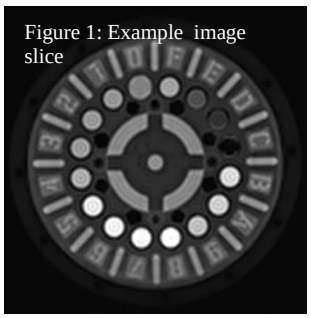
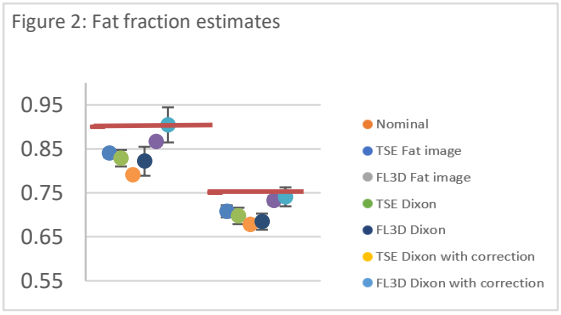


Figure 1: Example image slice



This study evaluates the bias and uncertainties obtained using Dixon imaging [2] on a clinical MRI system at 1.5 Tesla using a prototype phantom containing vials with different fat fractions, each of which has been independently verified using an alternative approach which is traceable to a primary SI unit. Figure 1 shows an example image of the complete phantom (vials 9 and A considered here).

Methods

Two-point Dixon images were acquired on a 1.5T Siemens Aera MRI scanner, using a 20-channel head/neck coil for both TSE and FLASH Dixon sequences. ROIs consisted of a central grouping of 9 voxel signals for each vial, chosen to reduce the effect of image distortion effects and Gibbs ringing. Three different sets of results were processed representing 1) Sequence determined PDFF, 2) Two-point Dixon determined PDFF and 3) Dixon PDFF plus a correction factor to account for fat spectral complexity.

Results

Figure 2 shows fat fraction estimates obtained using both sequences. Ground truth values are shown as solid lines for fat vials containing nominally 90% and 75% t-butanol, and error bars represent Type A Uncertainties from the spread of data. We observe that the signal from the sequence specific water suppressed images, as well as simple 2-point Dixon analysis consistently underestimates the PDFF of the phantom. FLASH Dixon based imaging displays closest agreement to nominal PDFF values, however, also displays significantly higher variation that TSE based sequences.

Discussion & Conclusions

3D Flash Dixon imaging with the multiple peak correction is the only method which does not show a significant bias compared to the nominal fat fraction. Corrected turbo spin-echo acquisitions show less bias than the remaining methods, but still shows a statistically significant bias. All other methods underestimate the fat fraction of the samples. The metrological traceability of the fat solution samples in the phantom allows us to unambiguously state that the 3D FLASH Dixon method is performing best, and not an outlier because the ground truth concentrations are known from an independent, traceable measure. This approach can be readily extended to assess and quantify inter-scanner variability and to include other type of quantitative MR measurements such iron content or diffusion.

Refs:[1] M Cashmore, et al British Journal of Radiology DOI 10.1259/bj4.20201215 (in press)
[2] WT Dixon, Radiology. 1984;153 (1): 189-94.

Experiences in running a successful commercial QA service in the US

Dr Moriel NessAiver, founder of simplyphysics.com

Moriel NessAiver started working in the field of MRI in 1985. He received his Ph.D. from the University of Southern California in 1988. His thesis topic was “Surface Coil Intensity Correction of Endo-Rectal Prostate Images.” After graduating he worked at Elscint for one year developing flow-compensated imaging sequences for spine imaging. He then worked at Picker MRI for five years where he was in charge of the Cardiac MRI research and development program. He was responsible for developing the first commercially released breath-hold cardiac cine package. Next, he became faculty at the University of Maryland Med School for 10 years. During his time there he wrote the popular textbook “All You Really Need to Know About MRI Physics.” Soon after that, in 2001, he joined the MRI Physics Subcommittee of the American College of Radiology which started his career in the field of MRI Quality Control. Since 2001, Dr. NessAiver, through his company Simply Physics, has performed over 1700 MRI Annual Performance Evaluations and has a database of RF coil tests performed numbering over 41,500 records.

Simply Physics is a family company located in Baltimore, Maryland. Much of the software used in the image analysis has been written by his two oldest sons. His third (of six) child will be joining his company later this year after she finishes her Ph.D. at Johns Hopkins University. Dr. NessAiver supports over 100 magnets spread out all over the USA, from Alaska to Puerto Rico. He uses the trips to perform the annual performance evaluation as an excuse to find new places to go fishing.

Accreditation of the MRI Physics Service in the UK

Dr Peter Jarritt, Chair of the UKAS MPACE Technical Advisory Committee.
Dr David Compton, UKAS

Peter Jarritt is a Chartered Scientist committed to the delivery of high quality, efficient and effective technology-based services in healthcare with a focus on facility design, commissioning, quality systems management and accreditation. With more than 30 years' experience directing and delivering a comprehensive range of Medical Physics and Clinical Engineering services at the highest level.

Peter is currently Executive Director and Medical Technology Lead of Healthcare Technology Solutions Ltd. He is also Deputy Director of the National Institute for Health, Brain Injury MedTech and *in vitro* Diagnostic Cooperative, supporting Medtech innovation in the brain injury pathway. In addition, Peter is a director of Orion MedTech, a spin out company delivering innovative products to the healthcare economy. He is also supporting the implementation of the East Midland and East of England Genomic Laboratory Hub at Cambridge University Hospitals leading on their Quality Management System implementation.

Peter was the Clinical Director and Head of Medical Physics and Clinical Engineering at Cambridge University Hospitals NHS Foundation Trust (Addenbrookes). Other Career highlights includes Chief Executive of Northern Ireland Regional Medical Physics Agency where he led design and development of a Cancer Centre and multiple imaging centres to deliver a range of services including Nuclear Medicine imaging and therapy services. Past projects also included development of multiple Positron Emission Tomography and associated cyclotron facilities.

He is an Honorary Fellow of the Royal College of Physicians as well as a Fellow of and Past President of the Institute of Physics and Engineering in Medicine.

David Compton graduated with a BEng (Hons) in Electrical and Electronic Engineering from Portsmouth University in 1993 and then completed a PhD at University College London in Electrical Engineering. David joined the Forensic Science Services (FSS) in 1997 working in the Research and Development team on a European Forensic Imaging project before establishing a range of digital forensic capability which obtained UKAS accreditation to ISO 17025. After leaving the FSS, David started as an Assessment Manager at the United Kingdom Accreditation Service (UKAS) with responsibility for undertaking assessment of organisation involved in testing, inspection and certification activities. In 2015 David moved into the development section as a Project Manager and since 2009 now the Section Head. David has responsibility for developing the UKAS accreditation scheme for Medical Physics and Clinical Engineering (MPACE) which awarded the first accreditation to BS 70000:2017 for Radiotherapy Physics and Clinical Engineering activities in October 2019. David is now working to extend the scope of MPACE accreditation to cover other medical physics and clinical engineering activities which support the delivery of diagnostic imaging services.

Abstract

As the UK's National Accreditation Body, UKAS has been appointed to manage and deliver the accreditation of Medical Physics and Clinical Engineering (MPACE) services. In October 2019 it awarded its first accreditation against BS 70000:2017 in the areas of Radiotherapy Physics and Management of Medical Devices. The MPACE project confirmed that BS 70000 is an applicable standard for providing 3rd party independent assurance on the competence of MPACE Services delivering reliable and safe services. The project is now expanding its remit to support other key MPACE activities which involve the commissioning, maintenance and ongoing quality assurance of diagnostic imaging equipment.

This presentation will provide a brief review of the background to BS 70000 and an update on the development of the UKAS accreditation programme. It will summarise the benefit and challenges encountered by Services involved in the original pilot programme and also address common questions such as the links between certification standards and the process of accreditation and the implications for Medical Physics and Clinical Engineering services. It will explore the links between MPACE and QSI as applied to Radiological Imaging and potential routes to harmonizing accreditation across services. The presentation will explore potential scopes of accreditation for MRI Physics services.

For up to date information on the MPACE please refer to :

MPACE-FAQ.pdf (ukas.com)

Quality assurance of breast MRI as part of the surveillance of women at higher risk in the UK

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Background. The NHS Breast Screening Programme (NHSBSP) is responsible for setting and monitoring the standards for the imaging surveillance of women who are assessed as being at higher risk of developing breast cancer. Report 68 [1] published in 2012 set out the technical standards required for the provision of breast MRI for this screening population, and described the requirements for quality assurance (QA). These included annual / start up / post major upgrade checks of contrast, the MR equipment and breast coil performance, and weekly checks, to include signal to noise ratio (SNR) and suppression effectiveness.

Methods. A questionnaire was sent out on the national MRI physics mailbase to gather preliminary data from centres performing breast MRI for screening purposes to investigate the QA being performed. Questions on QA acquisition and post-processing included what was being performed; how often; by whom; and how long it was taking. The responses received were collated and analysed in order to compare compliance with the guidelines [1] and variations in practices across centres in the UK.

Results. Responses from 13 MR groups, relating to 27 centres in total, were received (26 complete). QA on the breast MRI coil is performed in 23 (88%) of these centres and SNR measurements either involve manufacturer tests only (17%), some form of bespoke measurement only (74%), or a combination of both (9%). 22 (96%) centres perform suppression effectiveness. The most common manufacturer of the scanners at these centres was Siemens (61%), followed by Philips (22%) and then GE (17%). Of the 23 centres which follow the guidelines [1], 21 (91%) aim to perform tests weekly, one (4%) aims to perform tests monthly and one (4%) performs tests only prior to a breast list that includes a screening patient. One group reported that some centres fail to perform the tests weekly due to time constraints.

All centres following the guidelines [1] use protocols set up by clinical scientists. At all centres QA acquisition is performed by radiographers and was reported to take between 5-15 minutes, with an average of 9 minutes. Post-processing of the results is more varied. At 3 (14%) centres it is performed by a radiographer, at 11 (50%) centres it is performed by a clinical scientist and 8 (36%) use a combination of both. Post-processing was reported as taking between 5-10 minutes, with an average of 5 minutes.

Results on fault detection will be presented at the meeting.

Discussion. The results show there is generally good compliance with the guidelines [1]. The low uptake of manufacturer tests may be due to all sites having clinical scientist support facilitating bespoke QA measurements. At a small number of sites radiographers acquire and post-process the QA data, which may indicate that with sufficient training and support breast coil QA may not need routine clinical scientist supervision.

Conclusion. Amongst those sites that replied to the survey there is good compliance with the NHSBSP guidelines [1].

Key references.

1) Technical guidelines for magnetic resonance imaging (MRI) for the surveillance of women at higher risk of developing breast cancer, NHSBSP publication no. 68, 2012

Hazen: A free, open-source library for MRI QA analysis

[1]Shuaib H, [2]Heraghty N, [1]Ansell J, [1]Gabriel E, [1]Vilic D, [3]Wilson P,[1]Johnstone R, [1]Martin J, [1]McElroy S, [1]Franklin R, [1]Padormo F, [1]Price D, [1]O'Brien C, [1]Shah S,[1]Charles-Edwards G
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[2]Medical Physics, King's College Hospital NHS Foundation Trust, London, UK
[3]Northern Ireland Regional Medical Physics Service, Belfast Health and Social Care Trust, UK

Background

MRI acceptance testing and QA has achieved some standardisation in terms of test objects, imaging protocols and analysis methods. However, there are still requirements for more standardised and automated analyses using transparent algorithm implementations and with licensing that allows for commercial use. Hazen[1], named after the "father of modern optics" Hasan Ibn al-Haytham, is introduced as a free and open-source library that allows users to analyse DICOM images of test objects for automated QA analysis.

Methods

Hazen is implemented as a suite of Python modules with utility classes and functions that perform common tasks such as object detection. The core library can be called via a web service or a command line interface.

Results

Currently, Hazen has 9 committers including STP trainees and contributors external to Guy's & St Thomas' (GSTT). The following automated analysis routines have been implemented: signal-to-noise ratio (with or without measured slice width), slice position, slice width, spatial resolution, uniformity, ghosting & relaxometry. The images in figure 1 demonstrate a fully automated analysis of spatial resolution of an image using the Judy (1976) MTF method[2].

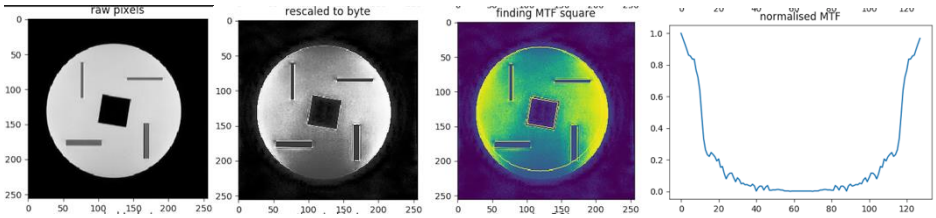

Figure 1. Output images of Hazen spatial resolution analysis using MTF method.

The core Hazen library has been successfully been used in 18 acceptance tests and QA visits since Jan 2020, on MR systems from Canon, GE, Philips and Siemens. The automated analysis saves significant processing time when performing image QA tests. To date, Hazen has been based upon MagNET phantoms, but is readily transferable to other test objects.

Discussion & Conclusion

Hazen is an open-source library for MRI QA analysis that can perform automated analysis and reporting of images acquired of standard QA test objects. The suite of analysis functions cover those commonly performed in an MRI acceptance test. Development of Hazen is led by the MR Physics group at GSTT with the ability to receive contributions from the MR community. The development roadmap includes a web application as an interface, pre-processing data verification, longitudinal monitoring and comparison with results from other systems of the same model/generation.

Reference

1. www.bitbucket.org/gsttmri/hazen
2. Judy, P.F. (1976) The line spread function and modulation transfer function of a computed tomography scanner. Medical Physics, Vol. 3, 233–236.

Big Data QA: Monitoring MRI Performance Through Clinical Images

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Background. MRI QA typically involves daily assessment of SNR through phantom measurement. This can fail to identify scanner issues for a number of reasons including: (1) An issue can be intermittent and therefore not captured by the daily QA sampling rate; (2) A phantom is a poor representation of a patient which may not reproduce a scanner malfunction; (3) Sequences implemented in daily QA often do not mimic clinically implemented sequences. One solution to circumvent these issues is QA based on clinical images [1]. This approach also has the benefit of not requiring dedicated system and personnel time for QA measurement.

Methods. Automated clinical image QA was implemented across 4 different 1.5T MR systems (two in house and 2 mobile units) and compared to manufacturer daily phantom based QA. FLAIR images were segmented to produce GM/WM/Skull/Background volumes using SPM (fil.ion.ucl.ac.uk/spm/) and image metrics were obtained from this segmentation including CNR, image bias index (uniformity), image resolution (based on the lines spread function across the cortical surface and a generalised quality index [1]. Phantom based QA was compared to clinical image QA to determine which provided a better indication of potential scanner malfunction

Results. In total 700 FLAIR images were analysed over a period of 12 months. Figure 1 shows phantom and clinical image data from two systems where the following image quality issues are highlighted: (1) Failed daily phantom QA. Clinical image QA did not show a corresponding poor quality and subsequent investigation highlighted operator error; (2) Coil element failure and subsequent coil replacement; (3) Intended FLAIR protocol change with reduced FOV.

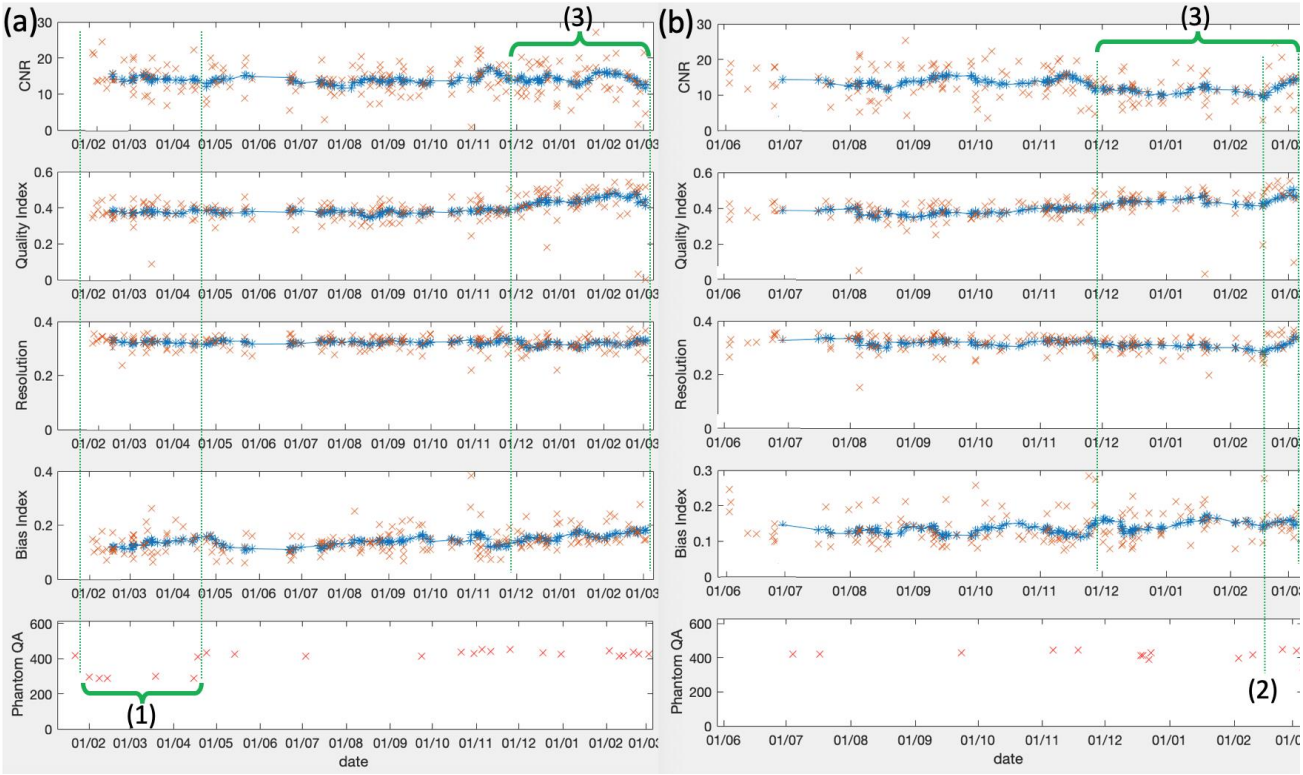

Fig 1. Clinical and Phantom QA results for scanners (a) and (b). Red = individual data points. Blue = Data averaged over 10 data points.

Conclusion. Clinical image QA potentially identified improved system performance when a malfunctioning coil was replaced. This was less apparent in phantom QA. Clinical image QA was also less susceptible to operator variation. We are currently looking to apply AI methods to better identify the known scanner issues including intermittent artefact on the FLAIR imaging

Key references. [1] Juha I Peltonen, et.al. MAGMA (2018) 31(6):689-699

Towards traceable quantitative phantoms for qMRI

Dr Kathryn Keenan, National Institute of Standards and Technology (NIST)

Kathryn Keenan, PhD is the Quantitative Magnetic Resonance Imaging (MRI) Project Leader at the National Institute of Standards and Technology (NIST) in Boulder, CO where she works to improve the repeatability and reliability of MRI.
Dr. Keenan started at NIST as an NRC post-doctoral scholar and created an MRI reference object (phantom) for assessing the accuracy and comparability of breast cancer imaging methods. Currently, she is developing methods to validate advanced quantitative MRI techniques. In 2019, Dr. Keenan won a Presidential Early Career Award for Scientists and Engineers (PECASE), and, in 2016, along with her colleagues, she won a Department of Commerce Gold Medal as well as the inaugural Department of Commerce Ron Brown Award for Excellence in Innovation.

Abstract

A bit more than a decade ago, the National Institute of Standards and Technology (NIST) embarked on a journey to develop and support standards for quantitative MRI. In that time, the group developed three reference objects or phantoms that are now commercial products, and the methods to measure T1 and T2 relaxation times to within +/- 2% uncertainty (http://doi.org/10.1002/mrm.28779 and https://doi.org/10.6028/NIST.SP.250-97). However, the process has not been smooth. Along the way we learned lessons about phantom materials (both the “hardware” and the chemical constituents) and benefits and drawbacks of choices we made. Now, in addition to supporting the phantoms that are out in the world, we are also developing strategies to validate and assess uncertainty of methods like magnetic resonance fingerprinting. The group is also developing phantoms for low magnetic fields (in this case anything less than 0.55 T) to support the new commercial efforts in this area.

In this talk, I’ll review lessons learned from phantom development, discuss our approach to measuring uncertainty for magnetic resonance fingerprinting, and present our interest and work in low field MRI.