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Research Article

A survey and analysis of radiotherapy linear accelerator quality control in the United Kingdom, for c-arm and ring gantry systems and associated patient specific quality control

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Abstract

Objectives: To conduct a survey of radiotherapy linear accelerator quality control (QC) across the United Kingdom (UK) on behalf of the Institute of Physics and Engineering in Medicine (IPEM) Radiotherapy Special Interest Group and Interdepartmental Dosimetry Audit (IDA) Sub-committee. To update results from a similar survey published in 2012 and compare to the latest guidance from IPEM Report 81 (2018). There have been significant developments of equipment and clinical practice since the previous survey and IPEM publication, requiring an updated review and benchmark of QC practice.

Methods: All UK radiotherapy centres were invited to complete a comprehensive survey of their local QC practice, with questions on c-arm gantry, ring-gantry, linac ancillary equipment, and patient-specific QC.

Results: 63% ($n = 43/68$) of the UK radiotherapy centres responded. IPEM Report 81 was used to inform QC practice in 91% of centres. For the majority of tests studied centres were meeting or exceeding the recommendations of this report. Standard output was still performed weekly in 26% of centres compared to monthly recommendation in Report 81. Comprehensive tables of frequency and tolerances of QC tests were collated for c-arm and ring gantry linacs and ancillary equipment.

Conclusions: A comprehensive review of consensus practice for linac QC radiotherapy across the UK is presented. Findings include the main stated reasons QC is undertaken is to "demonstrate safe use." On efficiency, it was found that about half of centres state they undertake "the right amount of QC." Half also state review of their QC process is "required."

Advances in knowledge: Updated data are presented on current practice for linac QC in the UK.

Keywords: UK; quality control; QC; radiotherapy; radiotherapy physics; survey; PSQC.

Introduction

Quality control (QC) testing is an essential component of the system for assurance of accuracy and safety in radiotherapy. As the complexity of equipment and clinical techniques continue to evolve, it is essential that QC testing is optimized for maximum value and efficiency, while meeting safety requirements and assuring best achievable accuracy. Since it falls to the responsibility of the local Medical Physics Expert (MPE)[1] to decide the scope of QC testing in radiotherapy departments, it is particularly useful to have recommendations, guidance, comparative data, and surveys of peer practice when producing QC testing schedules.

Previous surveys of QC practice in the UK have been valuable, with positive responses from physicists, conducted between 1999 and 2012[2-4] helping to shape and standardize practice and give confidence in approach to QC. In the United Kingdom (UK), the professional body for medical physicists, the Institute of Physics and Engineering in Medicine (IPEM), published guidance on physics aspects of QC in radiotherapy, Report 81, second edition, in 2018,[5] which also provided a valuable resource for design of QC schedules. However, the previous surveys and published professional guidance in the UK are now several years old and reference data may be in need of update, particularly to reflect changes in treatment technology and clinical practice; specifically, expansion of image guidance and online/offline plan adaptation, adoption of higher-precision techniques, ring-gantry linacs, and evolution of patient specific QC practice, initially for volumetric techniques (VMAT) and later for more complex stereotactic approaches (SABR).

The IPEM Interdepartmental Dosimetry Audit (IDA) Group on behalf of the IPEM Radiotherapy Special Interest Group, commissioned a survey of UK radiotherapy centres to establish current consensus practice for QC of radiotherapy linacs and associated equipment.

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Methods

A survey questionnaire on QC practice of radiotherapy linacs, was sent to all UK radiotherapy centres in August 2024. Responses were collected up until ~70% of centres had responded, which was through to November 2024.

The survey requested local measurement frequency and performance tolerance values against a comprehensive list of QC tests, taken from IPEM Report 81 (2018),[5] the most recent UK QC survey,[4] AAPM TG142,[6] and other relevant references[7,8] with unpublished QC schedules from individual radiotherapy centres. Responses were categorized into conventional c-arm gantry linacs and ring-gantry systems, and for QC of ancillary equipment. The local methodology and approach to patient specific quality control (PSQC) was also investigated. A review of various aspects of the management of QC functions was collated.

The questionnaire was piloted at 6 UK radiotherapy centres, to determine whether questions were explicit and interpreted correctly. Responses from the pilot survey were used to refine the final set of questions and pilot centres updated their responses to align with this official version.

A comprehensive list of all QC tests undertaken across all the responding centres in the UK was collated. To manage the amount of data and improve readability, only those tests conducted in at least 5 centres for c-arm gantry linacs, and 3 centres for ring-gantry linacs (due to a smaller sample size) were analysed and presented in this report. This empirical approach to data presentation maintained a true reflection of the full data. QC tolerances can be expressed in different units, such as % or mm, therefore the data was separately analysed and presented for each unit reported.

Results

The results of the QC survey are presented in 4 sections: QC management, frequency, tolerances, and patient specific QC (PSQC) considerations. The results for c-arm linacs are presented in this paper with the results for ring gantry and ancillary equipment presented in the Supplementary Material.

Forty-three UK centres responded to the survey providing comprehensive data on their QC schedules, procedures, and practice. Satellite centres were not separately invited but were asked to be included separately if QC processes differed to the lead centre.

The results are presented as a percentage of the total number of centres responding to the survey ($n = 43$ out of a possible 68) not as a percentage of centres responding to specific questions. Also, centres may have responded to more than one option in a question. Therefore, totals may be greater or less than 100%. Data from the previous survey[4] is also presented in this format (which differs from the original publication[4]) for ease of comparison. Survey responses that were unclear and could not be validated were not presented in the data tables.

Linacs manufactured by Varian Medical Systems (Palo Alto, CA) were installed in 58% of responding centres, with Elekta (Stockholm, Sweden) linacs installed in 37%, and linacs from both vendors in 5% of centres. The responses for Varian and Elekta linacs have been combined for this publication as there were no significant differences and to manage the size of data tables presented.

QC management

The stated main purpose of a QC schedule was to "demonstrate safe use of the machine" for 91% of centres. Other common themes were to "monitor performance" (21%), "prioritise measuring components that are known to drift" (21%), a "statutory requirement" (14%), and to "predict failing components" (12%). Only 5% of centres stated to test potential failure modes.

The periods within which linac QC is performed in UK centres is shown in Table 1 (ordered by frequency). There is a wide variety in how QC is scheduled, with almost twice as many (26%) centres using a combination of early morning and normal working day for their QC, compared to centres using evenings and weekends (14%). Table 2 presents a wide variation in the time required for performing linac QC at centres across the UK, with the total time, including offline analysis, ranging from 6 to 37 hours per linac per month.

A service efficiency machine (SEM) was available in 16% of centres. 37% of centres stated they have a managed equipment service. When asked who provides the preventative maintenance inspection (PMIs) 42% of centres stated they had a partnership with the vendor, 28% stated in house and 26% stated vendor only. 19% of centres performed PMIs monthly, 21% quarterly, and 21% 3 times/year with an overall range of monthly to 6 monthly. The time taken for PMIs is not included in the QC time data (Table 2).

IPEM Report 81 (2018)[5] was stated as being used in 91% of centres to derive their QC schedule with 67% of centres stating experience is also used. Only 5% of centres mentioned near misses inform QC schedules. 26% of centres review QC schedules annually, 26% stated with the introduction of new treatment techniques or equipment, and 23% stated when new guidance is published. 19% of centres stated they have no formal review schedule and 14% of centres stated they continually review. 12% of centres stated they had not completed a review since the publication of IPEM Report 81 (2018).[5] Only 1 centre stated a complete change of process moving from IPEM Report 81 (2018)[5] approach to a failure mode and effects analysis (FMEA) approach. 51% of centres stated their QC schedule is in need of update.

86% of centres stated they have improved the efficiency of their QC approach: 16% by reducing frequency, 16% by

Table 1. Periods in which linac QC is performed in UK radiotherapy centres.

Routine QC is performed	Percentage of centres using the combination of sessions														
	26%	14%	12%	9%	7%	5%	5%	2%	2%	2%	2%	2%	2%	2%	2%
Early Morning	✔			✔		✔		✔	✔	✔	✔	✔			
Normal Day	✔		✔		✔			✔	✔	✔			✔	✔	
Evening		✔			✔	✔		✔	✔		✔		✔		✔
Weekend		✔			✔	✔	✔	✔		✔		✔		✔	
Previous Survey Results (2012) [4]	5%	0%	30%	0%	7%	0%	0%	7%	12%	2%	0%	0%	30%	2%	5%

Table 2. Duration of linac QC performed per linac per month in UK radiotherapy centres (it is unclear if all centres included daily QC in their total).

Linac type	Time category (h per linac per month)	Minimum value	First quartile	Median	Third quartile	Maximum value
C-Arm	Total machine time	5	10	15	20	34
	Total offline analysis	0	1	2	2	15
	Total time	6	11	18	24	37
Ring	Total machine time	4	6	7	8	12
	Total offline analysis	0	0	2	2	8
	Total time	5	6	9	10	20

moving to online analysis, 16% by reordering tests. Half of centres stated they undertake the right amount of QC, 16% stated too much, 5% felt too much but uncomfortable reducing below IPEM Report 81 (2018)[5] recommendations and 5% stated too little.

Software was used in 2/3 of centres for recording QC results: most commonly QATrack+ (RADformation) (26%). Local spreadsheets and databases were used in 53% of centres and only 7% of centres reported they still use paper records for some or all their QC. Stated benefits of electronic recording included improved trending (47%), identification of out of tolerance results (28%), remote access (19%), and reduced human error (19%). One centre stated that trending of the results in this way helped to identify degradation of the target before breakdown.

Full completion of planned monthly QC was reported in 47% of centres, 35% stated above 95% completion, and 9% reported less than 75%. 37% of centres stated they routinely record compliance data as a key performance indicator, 49% of centres stated they do not, and 5% stated not currently but soon.

A linac would be removed from clinical use to complete monthly QC in only 19% of centres, and of these, half had a SEM. 44% stated they may remove functionality from a machine to return to use if QC had not been completed, in particular this related to electron energies being taken out of service.

QC frequency

IPEM Report 81 (2018)[5] was used to determine the frequency of performing QC in 86% of centres, 84% stated local experience/past trends/reviewing trends, 26% stated AAPM 142 Report[6] and 26% risk assessments. Most centres reported using published guidance as a starting point and making centre specific modifications from local experience and trending. 7% stated frequency is based upon what is practically achievable, only 1 centre stated using FMEA.

The frequency at which linac QC measurements were made at UK centres responding to the survey is presented in Table 3 for conventional c-arm gantry linacs. The data shows the current survey results compared to IPEM Report 81 (2018) recommendations[5] and the previous UK survey results.[4] Data for ring-gantry linacs and ancillary equipment are presented in the Supplementary Material.

QC tolerances

The survey used a definition of "notification" level, being the ideal operating performance above which investigations and rectification would be planned, and "suspension" level at which equipment is likely to be removed from clinical use. Terminology varied between centres with over 15 variations.

Published guidance was used in 95% of centres to determine the notification and suspension levels for the QC tests. 74% of centres also stated that tolerances were locally derived based on experience of expected machine performance. 49% of centres stated these tolerances are regularly reviewed and updated.

The variation of tolerance levels for QC tests is given in Table 4 for c-arm linacs. Ring-gantry linacs and linac ancillary equipment is presented in the Supplementary Material. The modal (most frequent) tolerance values are given, with multi-modal result if appropriate, in the format $n = x/y$ where x is the numbers of centres reporting modal value and y the total number of centres responding to each question in the stated units. "No consensus" is stated where no mode in the data and "functional" includes similar wording, eg, working, pass, on, yes/no.

Patient specific quality control

Independent monitor unit (MU) checks or point dose calculations were used in 41% of responding centres. The most commonly used software was RadCalc (Lifeline Software Inc., Tyler, United States) (35%), DoseCHECK (SNC, Mirion Medical, Florida, United States) (16%), and in-house solution (23%). 49% stated that an MPE would review failing plans to decide the course of action, 23% stated this may include sending the plan for measured PSQC and 16% stated it may include using a different measurement point.

Independent 3D dose calculations were completed for all (treatment planning system) TPS plans in 28% of centres, 23% stated all VMAT/IMRT plans, other centres restricting to specific categories, eg, stereotactic ablative body radiotherapy (SABR) or flattening filter free (FFF). The most commonly used software was SNC Patient (30%) and RadCalc (26%). 49% stated an MPE would be involved in the decision of how to proceed with a failing calculation with 42% stating their decision likely includes sending the plan for measurement.

The proportion of patient plans undergoing measured PSQC varied considerably between centres, but in the majority, it was a relatively small percentage of the total number of plans. 14% of centres stated 10% of all plans have measured PSQC, 9% stated 5% of plans, the remaining centres estimated values in the range 1%-100% of plans. 49% of centres reported that plans undergo measured PSQC when new sites/techniques/prescriptions/class solutions have been implemented, fail software PQSC and/or are for SABR/SRS. Other common responses stated randomly sampled plans (30%), particularly complex plans (21%) and plans falling outside MU or MU/Gy limits (19%).

The most common equipment used for measurement was Delta4 (ScandiDos, Sweden) (40%), EPID panel (mixed vendors) (30%), point dose (26%), and ArcCHECK (Mirion

Table 3. Frequency at which QC is performed at UK centres, for c-arm gantry linacs.

QC Test	IPEM Report 81 (2018)[5]	Most common frequency in the previous Survey Results (2012)[4]	Daily	At least weekly	Between weekly and monthly	Monthly	Between Monthly and Quarterly	Quarterly	Between quarterly and 6 Months	6 Months	Between 6 months and annually	Annually	Scheduled less frequent than annually	Commissioning Only	Performance drift/post breakdown	Not Performed	Not Applicable
Beam Quality—Photons																	
Energy check (TPR 20:10)	M	M (74%)				30%	5%	7%		5%		30%		14%	5%	2%	
Energy constancy G = 0°	M	M (74%)	14%	2%		47%		7%							2%	23%	
Energy constancy G ≠ 0°	A					5%	2%	19%	2%	7%		19%		5%	5%	35%	
PDD measurement	A	A (48%)										65%		19%	12%	7%	
Beam Quality—Electrons																	
Energy Ratios G = 0°	Q			2%	2%	40%	9%	23%				2%		2%	2%	7%	2%
Energy ratios at G ≠ 0°	A					2%		9%		5%		21%		7%	5%	44%	2%
PDD Measurement	A	A (48%)				2%						51%		21%	12%	9%	2%
Dosimetry—Photons																	
Definitive calibration	C R					2%						33%		21%	47%		
Output recalibration					2%										95%		
Standard output	M	M (52%)	2%	26%	5%	58%	7%								2%		
Output constancy: manufacturer integrated device	D	D (44%)	40%	2%												2%	
Output constancy: external constancy device	D	D (44%)	67%	14%											2%	2%	
Calibration check: manfacturer integrated device	6	M (35%)	2%			21%	4%	7%							7%	2%	2%
Calibration check: external constancy device	6	M (35%)	2%	2%		44%	4%	7%	2%						7%		7%
Output in clinical mode cf. service mode			5%	2%		9%		5%				5%		9%	21%	35%	2%
Output factors	A								2%			47%		40%		7%	
Effect of gantry rotation on output	Q	Q or 6 (52%)	2%			16%	2%	37%	2%	5%		23%		5%	2%	2%	
Linearity of dose with MU	A	Q or 6 (48%)				5%	2%	16%	2%	12%		51%		2%	2%	2%	
Linearity of dose with dose rate	A	Q or 6 (48%)	2%			2%	2%	14%	5%	16%		23%		5%	2%	21%	
MU1 and MU2 readout			12%	5%		33%	9%					7%			12%	19%	
Consistency of dose output	A		19%			14%		5%		5%		28%		9%	2%	9%	2%
Backup timer	A	M (12%)	5%	2%		12%				2%		12%		14%	2%	28%	16%
Dosimetry—Electrons																	
Definitive calibration						2%						28%		23%	42%		2%
Output recalibration					2%							2%			88%		2%
Standard output	M	M (52%)	2%	23%	5%	53%	9%										2%
Output constancy: manufacturer integrated device	D	D (44%)	30%	2%												5%	
Output constancy: external constancy device	D	D (44%)	58%	14%												2%	2%
Calibration check: manufacturer integrated device	6	M (35%)	2%	4%		16%	2%	5%		2%					5%	5%	
Calibration check: external constancy device	6	M (35%)		2%		35%	7%	5%	2%						5%	5%	5%
Output in clinical mode cf. service mode			2%	5%		5%			2%			2%		12%	19%	37%	9%
Effect of gantry rotation on output	A	Q or 6 (52%)				2%		9%		5%		33%		9%		30%	2%
Linearity of dose with MU	A	Q or 6 (48%)					2%	7%	2%	7%		21%		21%	2%	28%	2%
MU1 and MU2 readout			5%	5%		30%	7%					5%			16%	21%	5%

(continued)

Table 3. (continued)

QC Test	IPEM Report 81 (2018)[5]	Most common frequency in the previous Survey Results (2012)[4]	Daily	At least weekly	Between weekly and monthly	Monthly	Between Monthly and Quarterly	Quarterly	Between quarterly and 6 Months	6 Months	Between 6 months and annually	Annually	Scheduled less frequent than annually	Commissioning Only	Performance drift/post breakdown	Not Performed	Not Applicable
Consistency of dose output	A		16%			19%						12%		12%	5%	26%	2%
Backup timer	A	M (12%)	2%			5%	2%					7%		9%	5%	47%	14%
Applicator factors	A					2%		5%	2%	2%		33%	2%	37%		7%	2%
Applicator/insert interlocks			7%			23%		16%		5%		5%		16%	7%	7%	2%
Flatness and Symmetry—Photons																	
F&S quick check—manufacturer integrated device			35%	2%		2%										7%	
F&S quick check—external constancy device			40%	14%		2%										12%	
F&S G = 0°	M	M (57%)		2%	2%	76%	7%	5%	2%			5%			2%		
F&S G ≠ 0°	A	M (26%)	2%	2%		7%		37%	2%	7%		30%			2%	7%	
Manufacturer integrated cf. external constancy device						2%		2%	2%	2%		2%		7%	12%	26%	33%
Profiles with water tank	A	A (48%)							2%			53%		35%	7%	2%	
Flatness and Symmetry—Electrons																	
F&S quick check—manufacturer integrated device			40%	14%		2%										5%	
F&S quick check—external constancy device			33%	12%		2%										21%	
F&S G = 0°	M	M (57%)			2%	49%	9%	19%	5%			5%		2%		5%	2%
F&S G ≠ 0°	A	M (26%)				2%		12%	2%	5%		30%		5%		37%	2%
Manufacturer integrated cf. external constancy device						2%			2%	2%				7%	9%	37%	33%
Profiles with water tank	A	A (48%)							2%			37%		47%	7%	2%	2%
VMAT & MLC																	
Arc cf. static output			2%			14%		7%		5%		2%		9%		56%	
DMLC sweeping gap output at diff θ			2%	2%		23%	7%	16%		2%		2%		9%		30%	2%
VMAT DRGS	6			2%		40%		9%	2%	2%		2%		2%	2%	33%	
VMAT MLC speed				2%		42%	2%	7%	2%					7%	2%	30%	
MLC Picket Fence—G0°	M		5%	7%		63%	5%	5%	7%							7%	
MLC Picket Fence—Cardinal Gθ	M			5%		40%	2%	12%	7%	5%				9%	2%	14%	
Leakage through MLCs	Q	Q6 (26%)				12%		5%	2%	2%		21%		42%	12%	5%	
MLC dosimetric leaf gap						12%		7%				14%		28%	9%	19%	5%
Wedges																	
Wedge ratio Wθ = 60°		M (34%)	5%	5%		28%	2%	7%				2%		5%		9%	33%
Wedge ratio Wθ ≠ 60°						12%	2%			5%		9%		9%		14%	42%
Wedge ratio G ≠ 0°		Q6 (47%)		2%		7%		7%		2%		9%		14%		16%	33%
Wedge beam profile		Q6 (18%)	2%	2%		2%	2%	2%				5%		28%	2%	14%	33%
Radiation Alignment																	
Quick check of radiation field size			51%	5%	2%	30%	5%									2%	2%
Measurement of radiation field size						28%	9%	23%	2%	7%		2%		12%	14%	2%	
Alignment of radiation and field light at gantry zero, isocentre	Q	M (61%)	7%	2%		49%	5%	14%		7%		2%			7%	7%	
Alignment of radiation and field light at different gantry angles	Q					12%		12%		2%		2%		5%		58%	

(continued)

Table 3. (continued)

QC Test	IPEM Report 81 (2018)[5]	Most common frequency in the previous Survey Results (2012)[4]	Daily	At least weekly	Between weekly and monthly	Monthly	Between Monthly and Quarterly	Quarterly	Between quarterly and 6 Months	6 Months	Between 6 months and annually	Annually	Scheduled less frequent than annually	Commissioning Only	Performance drift/post breakdown	Not Performed	Not Applicable
Alignment of radiation and field light at extended FSD	A					7%		7%		2%		14%		5%	5%	56%	
Junction homogeneity	Q					28%	2%	14%	7%	2%				12%	2%	23%	
Radiation isocentre	6	Q6 (31%)	2%	2%		40%	9%	9%	2%	16%		14%		2%	2%		
FFF field size			2%			21%		2%				5%		7%		47%	9%
Optical Field Indication																	
Alignment of graticule with rotation			23%	9%	2%	40%	2%	5%				2%		5%		7%	2%
Quick check of light size	D	D (43%)	63%	5%	2%	19%									2%	7%	
Variation with field size	M	M (22%)	9%		2%	53%	7%	7%	2%	2%				5%	5%	5%	
Variation with collimator rotation			16%	9%	2%	42%		7%						5%	5%	12%	
Light field geometry			14%	2%		14%		5%						5%	5%	49%	
Rotation of floor about light field graticule				2%	2%	37%		9%						5%	9%	23%	2%
Test of each lightbulb (if applicable)			5%	2%	2%	16%	9%	7%	2%						14%	16%	21%
Couch Movements																	
Couch lat. and long.	M	M (44%)	26%	5%	2%	51%	5%	9%	2%			5%					
Couch vertical	M	M (35%)	26%	5%	2%	53%	5%	9%				5%					
Couch pitch and roll	M		9%	5%	2%	35%		12%		2%		2%				7%	23%
Couch rotation axis		M (31%)	12%	5%	2%	56%	2%	12%	2%			2%		2%		2%	2%
Couch deflection under load	A	A (30%)						7%				30%		23%	5%	30%	
Mechanical Alignment																	
Isocentre—Definitive Checks	A	A (31%)		5%		14%	5%	7%	2%	2%		30%		16%	7%	9%	
Isocentre—Quick checks	D M	WM (26%)	26%	5%		35%	5%	2%		2%						16%	
Isocentre—Manufacturer solution	M Q		5%	7%	2%	30%	2%	5%		5%		5%		7%	5%	5%	16%
Distance indicator	M	D (39%)	30%	9%	2%	42%	28%	9%	2%								
Gantry rotation	M	M (47%)	12%	7%		53%	7%	9%				2%			7%		
Collimator rotation	M	M (47%)	12%	7%		53%	7%	9%				2%			7%		
Electron applicator jaw readouts	Q	M (22%)				5%		23%		5%		19%		23%	5%	5%	2%
MV Imaging																	
Panel Calibration Check	M				2%	16%	2%	19%		5%		12%		2%	12%	9%	7%
Ghosting	A		2%			7%		5%		2%		16%		12%	9%	37%	2%
Contrast	Q	M (20%)		2%		33%	2%	21%	5%	5%		5%		2%	5%	9%	
Spatial Resolution	Q	M (20%)		2%		37%	2%	21%	5%	5%		2%		2%	7%	5%	
Uniformity	Q	M (20%)				35%	2%	16%	5%	2%		2%		9%	7%	12%	
Contrast to Noise Ratio	Q	M (20%)				26%	2%	14%	5%	5%				5%	5%	30%	
Image Scaling	M					40%	7%	14%	5%	2%		2%		5%	5%	5%	2%
Image centre alignment	M Q		16%	7%		26%	2%	9%	2%	2%		2%		5%	7%	5%	12%
Detector rotation	A			2%		14%		7%				5%		7%	5%	37%	9%
Detector position				2%		16%	2%	14%		5%	2%	5%		5%	9%	12%	9%
MV Dosimetry																	
Reference Plans						26%	5%	2%		2%		2%			5%	2%	
Dosimetry mode calibration check						16%	2%	2%						2%	7%	5%	

(continued)

Table 3. (continued)

QC Test	IPEM Report 81 (2018)[5]	Most common frequency in the previous Survey Results (2012)[4]	Daily	At least weekly	Between weekly and monthly	Monthly	Between Monthly and Quarterly	Quarterly	Between quarterly and 6 Months	6 Months	Between 6 months and annually	Annually	Scheduled less frequent than annually	Commissioning Only	Performance drift/post breakdown	Not Performed	Not Applicable
kV Imaging																	
Blade calibration and geometry	MQ A					12%	5%	14%	2%	7%				2%	12%	12%	23%
Flood field and pixel map recalibration						9%	5%	26%	2%	7%		14%			28%		2%
Ghosting	A		2%			7%	2%	2%		2%		16%		9%	9%	30%	7%
High and low contrast	Q	M (20%)				18%	5%	26%	9%	9%		7%			2%	8%	5%
Image distortion	A					9%	5%	9%	2%	2%		2%		7%	2%	33%	7%
Image scaling	M Q					42%	12%	16%	5%	2%				2%		5%	7%
Image centre alignment	M		16%	9%		28%	7%	9%	2%	2%		2%		2%	5%	9%	5%
Detector rotation	A					19%		7%		2%		7%		9%	2%	35%	5%
Source and detector position	M Q			4%		12%	5%	21%		5%	2%	12%			9%	12%	5%
Dose measurement						5%	2%	5%		5%		65%			2%	2%	5%
Registration and couch																	
Clinically representative	A		26%	5%		14%	5%		2%			7%		16%		7%	2%
Daily check	D		79%	4%												5%	
CBCT																	
High and low contrast	M Q		2%	2%	2%	25%	8%	29%	5%	2%		5%				8%	
Pixel signal value/HU calibration	M Q			2%	2%	23%	7%	23%	2%	2%		2%		5%	2%	14%	
Image scaling and orientation	M Q		2%	2%	2%	28%	12%	28%	5%	5%		2%				5%	
HU uniformity	M Q		2%	2%	2%	21%	12%	28%	5%	2%		2%		2%		5%	2%
Room lasers																	
Alignment of wall and overhead lasers			53%	7%	7%	19%	5%	2%							2%	2%	
Alignment of isocentre wall lasers with additional lower lasers (eg, lasers 20 cm below isocentre)			9%			12%		2%								21%	42%
Interlocks																	
Radiation protection survey		A (9%)	7%									30%	9%	42%	2%		
Maze entrance interlock	D	D (39%)	91%	5%			2%					2%					
Audio-visual monitors	D		91%				2%									7%	2%
Beam on indicator	D		95%			2%	2%										
Beam termination	M		93%	5%			2%										
Backup MU counter	M	M (9%)	72%	5%		7%	5%					2%			2%	5%	
Couch collision	W		35%	5%		12%						2%		7%		12%	19%
Gantry collision	W		51%	9%		14%				2%	2%	2%		7%		2%	2%

D, daily; W, weekly; M, monthly; Q, quarterly; 6, 6 monthly; A, annually; C, commissioning; R, repair.
CBCT = cone beam computed tomography; DMLC = dynamic multi leaf collimator; DRGS = dose rate gantry speed; F&S = flatness and symmetry; FSD = focus to skin distance; FFF = flattening filter free; HU = Hounsfield unit; kV = kilovoltage; MLC = multileaf collimator; MU = monitor unit; MV = megavoltage; PDD = percentage depth dose; TPR = tissue phantom ratio; VMAT = volumetric modulated arc therapy.
As close to as possible previous survey results included in table. Underlined text indicates the most common value for each parameter.

Table 4. Notification and Suspension tolerance levels for QC results at UK centres, for c-arm linacs.

QC Test	IPEM Report 81 (2018) Action[5]	Notification			Suspension		
		Most Frequent Answer (Mode)		Range	Most Frequent Answer (Mode)		Range
Beam Quality—Photons							
Energy check (TPR20/10)	1%	1%	$n = 9/26$	0.1%-1.5%	1%	$n = 16/30$	0.2%-3%
Energy constancy G = 0°	1%	1%	$n = 11/19$	0.5%-5%	1% ($n = 9/24$), 2% ($n = 8/24$)		0.5%-5%
		1 mm	$n = 1/1$				
Energy constancy G ≠ 0°	1%	1%	$n = 14/19$	0.5%-3%	1% ($n = 7/19$), 2% ($n = 6/19$)		0.5%-3%
PDD measurement		1 mm	$n = 6/12$	0.5-2.5 mm	1 mm	$n = 6/11$	1-2.5 mm
	2%	2%	$n = 5/12$	0.1%-2%	1%	$n = 7/13$	0.2%-3%
		(0.5 mm/2%)	$n = 1/1$				
		> 99%					
Beam Quality—Electrons							
Energy ratios G = 0°		1 mm ($n = 5/13$), 2 mm ($n = 5/13$)		0.7-2 mm	1 mm	$n = 14/18$	1-3 mm
		No consensus %	$n = 0/5$	1%-6%	No consensus %	$n = 0/6$	1%-6%
	Dz correct to within 2 mm (z range 30% to 80%)	1 mm change of PDI	$n = 3/3$		2 mm change of PDI	$n = 1/1$	
Energy ratios G ≠ 0°		1 mm	$n = 2/4$	1-2 mm	2 mm ($n = 4/8$), 1 mm ($n = 3/8$)		1-3 mm
		No consensus %	$n = 0/2$	1%-2%	3% ($n = 2/4$), 2% ($n = 2/4$)		2%-3%
					Consistent with G = 0°	$n = 1/1$	
	Dz correct to within 2 mm (z range 30% to 80%)	1 mm change of PDI	$n = 3/3$		2 mm change of PDI	$n = 1/1$	
PDD Measurement		1 mm	$n = 8/17$	0.5-2 mm	2 mm	$n = 10/19$	1-3 mm
	2%	1%	$n = 1/1$		1%	$n = 2/3$	1%-2%
Dosimetry—Photons							
Definitive calibration	0.5/1%[a]	1% ($n = 9/19$), 0.5% ($n = 7/19$)		0.5%-2%	2% ($n = 10/28$), 1% ($n = 10/28$)		0.5%-3%
Output recalibration		1.5% ($n = 9/22$), 1% ($n = 8/22$)		0.5%-2%	2%	$n = 18/27$	0.5%-3%
Standard output	2%	1.5%	$n = 17/40$	1%-2%	2%	$n = 26/38$	2%-4%
Output constancy: manufacturer integrated	3%	2%	$n = 4/12$	1%-2.5%	2%	$n = 10/14$	2%-5%
Output constancy: external constancy	3%	2%	$n = 16/31$	1%-3%	3% ($n = 12/28$), 2% ($n = 10/28$)		2%-5%
Calibration check: manufacturer integrated		1% ($n = 4/11$), 0.5% ($n = 4/11$)		0.5%-1.5%	1%	$n = 6/11$	0.5%-2%
Calibration check: external constancy		1%	$n = 12/23$	0.5%-2%	1% ($n = 8/24$), 2% ($n = 7/24$)		0.3%-3%
Output in clinical mode cf. service mode		1% ($n = 3/6$), 2% ($n = 2/6$)		0.3%-2%	1% ($n = 2/6$), 2% ($n = 2/6$)		0.3%-3%
					Consistent	$n = 1/1$	
Output factors	2%	1%	$n = 7/18$	0.25%-2%	2%	$n = 14/26$	0.5%-4%
Effect of gantry rotation on output	2%	1%	$n = 9/23$	0.5%-2%	2%	$n = 23/34$	1%-4%
Linearity of dose with MU	1%	1%	$n = 18/23$	0.5%-2%	1%	$n = 20/33$	1%-5%
		Varies with MU	$n = 1/1$		Varies with MU	$n = 2/2$	

(continued)

Table 4. (continued)

QC Test	IPEM Report 81 (2018) Action[5]	Notification			Suspension		
		Most Frequent Answer (Mode)		Range	Most Frequent Answer (Mode)		Range
Linearity of dose with dose rate	1%	1%	$n = 12/18$	0.4%-3%	1%	$n = 14/23$	0.5%-5%
MU1 and MU2 readout	Functional						
		1 MU	$n = 7/12$	0.5-2 MU	2 MU	$n = 7/12$	1-5 MU
		No consensus %	$n = 0/2$	2%-5%	2%	$n = 6/9$	1%-2%
Consistency of dose output	0.5%	0.5% ($n = 7/20$), 1% ($n = 6/20$), 2% ($n = 5/20$)		0.4%-2%	0.5%	$n = 10/25$	0.25%-3%
		0.005 Gy	$n = 1/1$		0.01 Gy	$n = 1/1$	
Backup timer	Functional				Functional	$n = 3/3$	
		10%	$n = 2/3$	2%-10%	5%	$n = 2/3$	2%-5%
		No consensus s	$n = 0/3$	0.5s—10s	No consensus s	$n = 0/2$	0.5-10 s
		0.01 min	$n = 1$				
		0.5 MU	$n = 1/1$		No consensus MU	$n = 0/2$	0.1-1 MU
					Baseline	$n = 1/1$	
Dosimetry—Electrons							
Definitive calibration	0.5/1%[a]	1% ($n = 9/20$), 0.5% ($n = 8/20$)		0.5%-2%	1%	$n = 12/27$	0.5%-3%
Output recalibration		1.5% ($n = 8/20$), 1% ($n = 8/20$)		0.5%-2%	2%	$n = 16/25$	0.5%-3%
Standard output	2%	1.5% ($n = 16/37$)		1%-2%	2%	$n = 22/38$	2%-4%
Output constancy: manufacturer integrated	3%	2% ($n = 4/9$), 1.8% ($n = 3/9$)		1.5%-2%	2%	$n = 9/11$	2%-5%
Output constancy: external constancy	3%	2%	$n = 12/25$	1%-3%	3%	$n = 15/28$	2%-5%
Calibration check: manufacturer integrated		1% ($n = 3/8$), 0.5% ($n = 2/8$)		0.5%-1.5%	1% ($n = 4/9$), 2% ($n = 3/9$)		0.5%-2%
Calibration check: external constancy		1%	$n = 11/17$	0.5%-2.0%	2% ($n = 8/21$), 1% ($n = 8/21$)		0.3%-2%
Output in clinical mode cf. service mode		1% ($n = 3/5$), 2% ($n = 2/5$)		1%-2%	3%	$n = 2/3$	2%-3%
					Consistent	$n = 1/1$	
Effect of gantry rotation on output	2%	2% ($n = 5/16$), 1.5% ($n = 4/16$), 1% ($n = 4/16$)		0.5%-3%	2%	$n = 10/19$	1%-3%
					Consistent	$n = 1/1$	
Linearity of dose with MU	2%	1%	$n = 6/11$	0.5%-2%	1%	$n = 10/18$	1%-3%
					Various	$n = 1/1$	
MU1 and MU2 readout		1 MU	$n = 6/12$	0.5-2 MU	2 MU	$n = 5/10$	1-5 MU
	1%	No consensus %	$n = 0/2$	1%-2%	2%	$n = 3/5$	1%-2%
Consistency of dose output	1%	1%	$n = 8/16$	0.5%-2%	0.5%	$n = 5/16$	0.5%-3%
					1%	$n = 4/16$	
		0.007 Gy	$n = 1/1$		0.01 Gy	$n = 1/1$	
Backup timer	Functional				Functional	$n = 3/3$	
		No consensus s	$n = 0/2$	1-10 s	10 s	$n = 1/1$	
		No consensus %	$n = 0/2$	0.5%-10%	No consensus %	$n = 0/3$	0.3%-5%
		0.01 mins	$n = 1/1$				
					Baseline	$n = 1/1$	
Applicator factors	2%	2%	$n = 8/13$	1%-2%	2%	$n = 12/17$	1%-4%

(continued)

Table 4. (continued)

QC Test	IPEM Report 81 (2018) Action[5]	Notification			Suspension		
		Most Frequent Answer (Mode)		Range	Most Frequent Answer (Mode)		Range
Applicator/insert interlocks	Functional	Functional 2%	$n = 5/5$ $n = 1/1$		Functional 3%	$n = 10/10$ $n = 1/1$	
Flatness and Symmetry—Photons							
F&S quick check—manufacturer integrated		1.8% ($n = 5/12$), 2% ($n = 4/12$)		1%-2%	2%	$n = 8/10$	2%-5%
F&S quick check—external constancy		2%	$n = 10/20$	1%-3%	3%	$n = 12/23$	1.5%-5%
Flatness scans G = 0°	2%	2% 1/1.5% Baseline	$n = 11/29$ $n = 1/1$ $n = 1/1$	0.5%-2.5%	2%	$n = 19/35$	1%-3%
Symmetry scans G = 0°	2%	2%	$n = 18/36$	0.5%-2.5%	2%	$n = 23/38$	1.5%-4%
F&S G ≠ 0°	2%	2%	$n = 13/32$	0.5%-3%	2% ($n = 11/29$), 3% ($n = 10/29$)		0.5%-3%
Manufacturer integrated cf. external constancy		No consensus %	$n = 0/6$	0.5%-3%	No consensus %	$n = 0/7$	1%-3%
Profiles with water tank	2%	2% ($n = 6/15$), 1% ($n = 5/15$) No consensus	 $n = 0/2$	0.5%-3% 1-2%/mm	2%	$n = 12/23$	1%-4%
Flatness and Symmetry—Electrons							
F&S quick check—manufacturer integrated		1.8% ($n = 4/9$), 2% ($n = 3/9$)		1-2%	2%	$n = 5/9$	2%-5%
F&S quick check—external constancy		2% ($n = 6/16$), 3% ($n = 5/16$)		1%-3%	3%	$n = 11/19$	1.5%-5%
Flatness G = 0°	2%	2% ($n = 8/26$), 1.5% ($n = 7/26$)		0.5%-5%	2%	$n = 11/30$	1%-6.5%
Symmetry G = 0°	2%	2%	$n = 15/32$	0.7%-2%	3% ($n = 15/36$), 2% ($n = 15/36$)		1.5%-4%
F&S G ≠ 0°	2%	2%	$n = 8/18$	1%-2%	2%	$n = 9/19$	1%-3%
Manufacturer integrated cf. external constancy		No consensus	$n = 0/6$	0.5%-3%	No consensus	$n = 0/4$	1%-3%
Profiles with water tank	2%	2% ($n = 5/13$), 1% ($n = 4/13$) 1.5 mm 1%/1 mm	 $n = 1/1$ $n = 1/1$	0.5%-3%	2% ($n = 7/19$), 1% ($n = 6/19$) 2 mm	 $n = 1/1$	1%-4%
VMAT & MLC							
Arc vs static output	2%	2% ($n = 5/12$), 1% ($n = 4/12$)		0.5%-2%	No consensus	$n = 0/11$	1%-4%
DMLC sweeping gap output at diff. θ		2% 0.2 mm 0.015 ratio	$n = 9/11$ $n = 1/1$ $n = 1/1$	1.5%-2%	2% 0.5 mm	$n = 7/14$ $n = 1/1$	1.2%-4%
VMAT DRGS	2%	2% 0.02 ratio	$n = 7/14$ $n = 1/1$	0.5%-3%	2% 0.3 °/s	$n = 9/16$ $n = 1/1$	1%-3%
VMAT MLC speed		2% ($n = 5/13$), 1.5% ($n = 4/13$) 0.02 ratio	 $n = 1/1$	0.5%-5%	3% ($n = 6/13$), 2% ($n = 5/13$) 0.3 cm/s	 $n = 1/1$	1%-3%
MLC Picket Fence—G0°	1 mm	0.5 mm Visual check Any leaf/junctions >1.5 but ≤ 2.0 mm	$n = 9/24$ $n = 2/2$ $n = 1/1$	0.15-1 mm	1 mm Visual check 5%	$n = 13/26$ $n = 1/1$ $n = 1/1$	0.25-2 mm

(continued)

Table 4. (continued)

QC Test	IPEM Report 81 (2018) Action[5]	Notification			Suspension		
		Most Frequent Answer (Mode)		Range	Most Frequent Answer (Mode)		Range
MLC Picket Fence—Cardinal Gθ		0.5 mm	$n = 6/18$	0.2-10 mm	1 mm	$n = 10/19$	0.25-5 mm
		Visual check	$n = 2/2$		Visual	$n = 1/1$	
		Any leaf/junctions >1.5 but ≤ 2.0 mm	$n = 1/1$				
Leakage through MLCs[b]		0.5%	$n = 7/17$	0.1%-2.5%	No consensus	$n = 0/17$	0.09%-5%
MLC dosimetric leaf gap		No consensus	$n = 0/9$	0.025-0.2 mm	0.2 mm	$n = 4/10$	0.05-0.3 mm
		0.1 mm and 0.2 mm	$n = 1/1$				
		2%	$n = 1/1$		2%	$n = 1/1$	
Wedges							
Wedge ratio Wθ = 60°	1%	1% ($n = 6/13$), 2% ($n = 5/13$)		1%-3%	2%	$n = 6/15$	1%-4%
Wedge ratio Wθ ≠ 60°	1%	1%	$n = 5/11$	0.5%-2%	2% ($n = 4/10$), 1% ($n = 3/10$)		1%-3%
Wedge ratio G ≠ 0°	1%	2% ($n = 5/12$), 1% ($n = 4/12$)		1%-3%	3% ($n = 5/12$), 2% ($n = 4/12$)		1%-4%
Wedge beam profile	2%	2%	$n = 5/6$	1%-2%	3% ($n = 3/9$), 2% ($n = 3/9$)		1%-4%
		1°	$n = 1/1$				
Radiation Alignment							
Quick check of radiation field size		1 mm	$n = 15/31$	0.8-3 mm	2 mm	$n = 18/32$	1-4 mm
		0.8X 1.8Y mm	$n = 1/31$		1X 2Y mm	$n = 1/32$	
Measurement of radiation field size		1 mm	$n = 18/33$	0.7-2 mm	2 mm	$n = 20/36$	1-3 mm
		1 mm on individual jaw	$n = 3/3$		1 mm on individual jaw ($n = 2/3$), 2 mm on individual jaw ($n = 1/3$)		
		1 mm stereotactic 2 mm other	$n = 1/1$				
					2 mm on jaw and 3 overall	$n = 1/1$	
					Field size dependent	$n = 2/2$	
		1 mm and 1°	$n = 1/1$		2 mm and 2°	$n = 1/1$	
Alignment of radiation and field light at gantry zero, isocentre	2 mm (1 mm precision)	1 mm	$n = 11/31$	1-3 mm	2 mm	$n = 19/32$	1-5 mm
		1 mm on individual jaw	$n = 2/2$		1 mm on individual jaw ($n = 1/2$), 2 mm on individual jaw ($n = 1/2$)		
					Field size dependent	$n = 2/2$	
		1 mm and 1°	$n = 1/1$		2 mm and 2°	$n = 1/1$	
Alignment of radiation and field light at different gantry angles		1 mm	$n = 6/14$	0.5-2 mm	2 mm	$n = 8/13$	1-4 mm
		1 mm on individual jaw	$n = 1/1$				
					1 mm on individual jaw 2 mm overall	$n = 1/1$	
		1mm and 1°	$n = 1/1$		2 mm and 2°	$n = 1/1$	
Alignment of radiation and field light at extended FSD		1 mm	$n = 6/15$	1-4 mm	2 mm	$n = 11/17$	1-6 mm
		1 mm on individual jaw	$n = 1/1$				
					1 mm on individual jaw, 2 overall	$n = 1/1$	

(continued)

Table 4. (continued)

QC Test	IPEM Report 81 (2018) Action[5]	Notification			Suspension		
		Most Frequent Answer (Mode)		Range	Most Frequent Answer (Mode)		Range
Junction homogeneity	2 mm 20%	1 mm No consensus 8 of expected 2 mm 70/120% Normal range %	$n = 8/10$ $n = 0/3$ $n = 1/1$ $n = 1/1$ $n = 1/1$	1-2 mm 7%-20%	2 mm No consensus 50% < dose at junction < 140%	$n = 8/10$ $n = 0/5$ $n = 1/1$	2-4 mm 10-50%
Radiation isocentre	2 mm	1 mm 2 mm 70/120% 0.7 mm SABR 1 mm other	$n = 14/26$ $n = 1/1$ $n = 1/1$	0.3-2 mm	2 mm($n = 10/28$), 1 mm($n = 9/28$)		0.5-3 mm
FFF field size		1 mm ($n = 3/8$), 2 mm ($n = 2/8$) 1.5%	 $n = 1/1$	0.5-3 mm	2 mm No consensus	$n = 5/12$ $n = 0/3$	0.7-5 mm 1%-20%
Optical Field Indication							
Alignment of graticule with rotation	2 mm	1 mm	$n = 17/25$	0.5-2 mm	2 mm	$n = 16/31$	0.5-4 mm
Quick check of light size	2 mm	2 mm	$n = 12/23$	1-2 mm	2 mm	$n = 23/31$	1-5 mm
Variation with field size	2 mm	1 mm X1 Y1 X2 Y2: 1 mm Total X and Y: 2 mm	$n = 14/24$ $n = 1/1$	1-2 mm	2 mm X1 Y1 X2 Y2: 2 mm Total X and Y: 3 mm	$n = 18/33$ $n = 1/1$	1-4 mm
Variation with collimator rotation		1mm	$n = 13/22$	0.5-2 mm	2 mm	$n = 13/28$	1-3 mm
Light field geometry		1° ($n = 3/5$), 2° ($n = 2/5$) 2 mm	 $n = 2/2$	1°-2°	2° 2 mm ($n = 2/5$), 3 mm ($n = 2/5$) 1%	$n = 3/4$ $n = 1/1$	2°-3° 2-3 mm
Rotation of floor about light field graticule		1 mm ($n = 7/15$), 2 mm ($n = 7/15$) 0.5°	 $n = 1/1$	1-2 mm	2 mm No consensus	$n = 11/21$ $n = 0/3$	1-3 mm 0.5°-2°
Test if each lightbulb (if applicable)		0.5 mm	$n = 5/9$	0.5-2 mm	1 mm 2%	$n = 5/13$ $n = 1/1$	0.5-3 mm
Couch Movements							
Couch—lat, long	2 mm	2 mm	$n = 12/26$	0.63-2 mm	2 mm 2%	$n = 20/35$ $n = 1/1$	0.7-4 mm
Couch—vert	2 mm	2mm	$n = 12/25$	0.63-2 mm	2 mm 2%	$n = 19/35$ $n = 1/1$	0.7-4 mm
Couch—pitch, roll	2 mm/1°	0.2° ($n = 3/18$), 0.3° ($n = 3/18$), 1° ($n = 3/18$),		0.09°-1°	0.5°	$n = 7/21$	0.1°-2°
Couch rotation axis		1.0° No consensus 1 (standard couch)/0.5 (HexaPod) Degree	$n = 7/21$ $n = 0/2$ $n = 1/1$	0.09°-2° 1-2 mm	0.5° ($n = 8/27$), 1° ($n = 7/27$) 2 mm	 $n = 2/4$	0.1°-3° 2-4 mm
Couch deflection under load	5 mm/0.5°	5 mm ($n = 4/11$), 2 mm ($n = 4/11$)		0.3-7 mm	5 mm($n = 6/17$), 2 mm($n = 5/17$) 5 mm/0.5°	 $n = 1/1$	0.5-10 mm

(continued)

Table 4. (continued)

QC Test	IPEM Report 81 (2018) Action[5]	Notification			Suspension		
		Most Frequent Answer (Mode)		Range	Most Frequent Answer (Mode)		Range
Mechanical Alignment Checks							
Isocentre—Definitive Checks	2 mm	1 mm	$n = 10/18$	0.5-2 mm	2 mm	$n = 12/24$	0.3-4 mm
		1 mm (stereotactic) or 2 mm (other)	$n = 1/1$				
Isocentre—Quick checks	2 mm (1 mm precision)	1 mm	$n = 10/16$	0.45-2 mm	2 mm	$n = 12/24$	0.5-4 mm
Isocentre—Manufacturer	Manufac.	0.5 mm($n = 5/12$), 1 mm($n = 4/12$)		0.3-1 mm	0.5 mm	$n = 7/14$	0.4-2 mm
					Pass	$n = 1/1$	
		Various	$n = 1/1$		Various	$n = 1/1$	
Distance indicator	2 mm	2 mm	$n = 12/26$	0.5-3 mm	2 mm	$n = 17/31$	0.5-3 mm
		2 mm at iso 3 mm at FSD ≠ 0	$n = 1/1$		2 mm at iso 5 mm at FSD ≠ 0	$n = 1/1$	
					1°	$n = 1/1$	
Gantry rotation	0.5°	0.3° ($n = 8/25$), 0.5° ($n = 8/25$)		0.2°-1°	0.5°	$n = 14/29$	0.2°-1°
		1 mm	$n = 1/1$		2 mm	$n = 1/1$	
Collimator rotation	0.5°	0.5°	$n = 9/25$	0.2°-1°	0.5°	$n = 16/30$	0.2°-1°
		1 mm	$n = 1/1$		2 mm	$n = 2/2$	
Electron applicator jaw readouts	Readouts correct	0 mm ($n = 6/14$), 1 mm ($n = 5/14$)		0-2 mm	0 mm	$n = 11/21$	0-3 mm
MV Imaging							
Panel Calibration Check	[c]	No consensus	$n = 0/4$	0.5%-5%	1%	$n = 2/4$	1%-10%
					Function	$n = 1/1$	
					Baseline	$n = 1/1$	
					Automated Calibration	$n = 1/1$	
Contrast	[d]	10%	$n = 2/8$	0.5%-10%	45%	$n = 2/6$	1%-45%
		Machine/ mode specific	$n = 2/2$		Machine/ mode specific	$n = 1/1$	
		No consensus	$n = 0/2$	0.61-0.77	No consensus	$n = 0/2$	0.6-0.68
		No consensus	$n = 0/2$	4-20 discs	No consensus	$n = 0/3$	4-20 discs
		Right hand 3 columns visible	$n = 1/1$				
		Various	$n = 1/1$		Various	$n = 1/1$	
					Baseline	$n = 1/1$	
					2mm, 4 mm	$n = 1/1$	
Spatial Resolution	[d]	0.1 lp/mm	$n = 3/10$	0.1-0.3 lp/mm	0.2 lp/mm	$n = 3/12$	0.15-15 lp/mm
					0.19 lp/mm	$n = 2/12$	
		Machine/ mode specific	$n = 2/2$		Machine/ mode specific	$n = 2/2$	
		No consensus	$n = 0/3$	5%-30%	30%	$n = 2/4$	7.5%-45%
		0.4	$n = 2/2$				
		2 mm	$n = 1/1$		3 mm	$n = 1/1$	
					20 discs	$n = 1/1$	

(continued)

Table 4. (continued)

QC Test	IPEM Report 81 (2018) Action[5]	Notification			Suspension		
		Most Frequent Answer (Mode)		Range	Most Frequent Answer (Mode)		Range
Uniformity	[d]	Machine/ mode specific	$n = 1/1$		Machine/ mode specific	$n = 1/1$	
		Visual Check	$n = 1/1$		Visual Check	$n = 2/2$	
		CoV > 3.5	$n = 1/1$				
		No consensus	$n = 0/11$	0.15%-99%	No consensus	$n = 0/12$	1%-99.8%
					Baseline	$n = 1/1$	
Contrast to Noise Ratio	[d]	Machine/ mode specific	$n = 2/2$		Machine/ mode specific	$n = 3/3$	
		10%	$n = 2/3$	0.5%-10%	15%	$n = 2/4$	1%-4%
		No consensus	$n = 0/6$	2.14-750	No consensus	$n = 0/4$	3.5-675
					Baseline	$n = 1/1$	
Image Scaling	1 mm over 100 mm	1 mm	$n = 13/19$	0.8-2 mm	2 mm	$n = 9/19$	1-3 mm
		0.1%	$n = 1/1$		No consensus	$n = 0/3$	0.2%-2%
		0.1 cm	$n = 1/1$		0.15 cm	$n = 1/1$	
					Baseline	$n = 1/1$	
Image centre alignment	2 mm	1 mm	$n = 5/15$	0.45-2 mm	2 mm	$n = 6/19$	0.05-4 mm
					0.5 mm	$n = 5/19$	
					Baseline	$n = 1/1$	
Detector rotation	Manufac.	1°	$n = 2/4$	0.2°-1.5°	2°	$n = 3/5$	0.2°-2°
					2 mm	$n = 1/1$	
					Baseline	$n = 1/1$	
Detector position	2 mm	1 mm ($n = 7/14$), 2 mm ($n = 7/14$)		0.5-3 mm	2 mm	$n = 5/11$	0.5-4 mm
		Lat/Lng: 1 mm Vrt: 2 mm	$n = 1/1$		Lat/Lng: 2 mm Vrt: 4 mm	$n = 1/1$	
					Baseline	$n = 1/1$	
MV Dosimetry							
Reference plans		No consensus	$n = 0/3$	95%-99%	No consensus	$n = 0/4$	3%-98.5%
					Pass Gamma 99% F0, 95% FN	$n = 1/1$	
					Functional	$n = 1/1$	
					3%/3 mm 95%	$n = 1/1$	
Dosimetry mode calibration check		0.5% ($n = 2/7$), 1.5% ($n = 2/7$)		0.5%-5%	1% ($n = 4/12$), 2% ($n = 3/12$)		0.5%-10%
kV Imaging							
Blade calibration and geometry	Manufac.[e]	5 mm ($n = 3/14$), 2.5 mm ($n = 3/14$), 2 mm ($n = 3/14$)		1-10 mm	5 mm	$n = 4/12$	2-20 mm
		0.5 cm	$n = 1/1$		1 cm	1/1	
High contrast	[d]	10 lp	$n = 4/11$	0.1-12 lp	No consensus	$n = 0/6$	0.2-12 lp
		1.4 lp/mm	$n = 3/5$	0.1-1.4 lp/mm	1.4lp/mm	$n = 2/4$	0.2-6 lp/mm
		No consensus	$n = 0/2$	Baseline -2 - Baseline -1			
		Machine Specific	$n = 1/1$		Machine Specific	$n = 1/1$	
		1%	$n = 1/1$		1.5%	$n = 1/1$	
		0.5	$n = 1/1$		0.53	$n = 1/1$	
					No consensus	$n = 0/2$	9-10 groups

(continued)

Table 4. (continued)

QC Test	IPEM Report 81 (2018) Action[5]	Notification			Suspension		
		Most Frequent Answer (Mode)		Range	Most Frequent Answer (Mode)		Range
Low contrast	[d]	12 discs	$n = 6/12$	10-15 discs	12 discs	$n = 4/8$	8-18 discs
		Baseline-1	$n = 2/3$	Baseline -2 -Baseline -1	Baseline -2	$n = 1/1$	
		No consensus	$n = 0/2$	1%-10%	No consensus	$n = 0/2$	1.5%-11.5%
		0.44	$n = 1/1$		0.39	$n = 1/1$	
		0.1 lp/mm	$n = 1/1$				
					Machine/ mode specific	$n = 1/1$	
Image distortion	2 mm over whole detector	1 mm	$n = 3/5$	0.4-2 mm	2 mm	$n = 2/4$	1-4 mm
		2%	$n = 1/1$		0.5%	$n = 2/3$	0.5%-2%
		1.5 mm V/H 2.5 mm Dia	$n = 1/1$				
Image scaling	1 mm over 100 mm	1 mm	$n = 13/20$	0.8-2 mm	1 mm ($n = 7/18$), 2 mm ($n = 6/18$)		1-3 mm
		0.8%	$n = 1/1$		No consensus	$n = 0/2$	1.5% - 2%
		1.5 mm V/H 2.5 mm Dia	$n = 1/1$				
Image centre alignment	2 mm	0.5 mm ($n = 4/15$), 2 mm ($n = 4/15$), 1 mm ($n = 3/15$)		0.05 - 2.5 mm	1 mm	$n = 6/15$	0.05-4 mm
					15-60 mm	$n = 1/1$	
Detector rotation	Manufac.	0.2°	$n = 2/5$	0.2°-1.0°	2°	$n = 2/3$	0.5°-2°
		No consensus	$n = 0/2$	1-2.5 mm	2 mm	$n = 2/3$	1.5-2 mm
Source and detector position	2 mm	1 mm ($n = 5/13$), 2 mm ($n = 4/13$)		0.5-10 mm	2 mm	$n = 7/11$	0.5-10 mm
					Baseline	$n = 1/1$	
					10 pixels	$n = 1/1$	
		Lat/Lng: 1 mm Vrt: 2 mm	$n = 1/1$		Lat/Lng: 2 mm Vrt: 4 mm	$n = 1/1$	
Dose measurement	[f]	10%	$n = 3/6$	−20%-10%	10%	$n = 6/9$	10%-30%
					Various	$n = 1/1$	
		Baseline	$n = 2/2$		Baseline	$n = 1/1$	
		0.5 mm	$n = 1/1$		1.5 mm	$n = 1/1$	
Registration and couch							
Clinically representative	2 mm (1 mm SRS/SABR)	1 mm($n = 5/14$), 1.5 mm($n = 5/14$)		0.5-2 mm	2 mm	$n = 7/16$	0.95-4 mm
		No consensus	$n = 0/2$	1%-2%	No consensus	$n = 0/2$	2%-3%
Daily check	2 mm (1 mm SRS/SABR)	2 mm	$n = 7/21$	0.2-2 mm	2 mm	$n = 14/25$	0.2-4 mm
		1 mm	$n = 6/21$				
CBCT							
High contrast	[d]	FOV Dependent	$n = 0/2$	4 or 5-5 or 6			
		Mode/ Machine specific	$n = 6/6$		Mode/ Machine specific	$n = 4/4$	
		Baseline	$n = 2/2$		Baseline	$n = 1/1$	
		No consensus	$n = 0/8$	0.1-11 lp	0.2 lp	$n = 2/13$	0.2-13 lp
		No consensus	$n = 0/2$	(3.3-4.9) -10 lp/cm	No consensus	$n = 0/2$	(2.8-4.4) -9 lp/cm
		No consensus	$n = 0/2$	0.07-0.255467 lp/mm	0.1 lp/mm	$n = 1/1$	
					Various	$n = 1/1$	

(continued)

Table 4. (continued)

QC Test	IPEM Report 81 (2018) Action[5]	Notification			Suspension		
		Most Frequent Answer (Mode)		Range	Most Frequent Answer (Mode)		Range
Low contrast	[d]	Mode specific	$n = 6/6$		Mode specific	$n = 1/1$	
		No consensus	$n = 0/2$	1-2 discs	No consensus	$n = 0/2$	4-9 discs
		Commissioning	$n = 1/1$		Commissioning	$n = 2/2$	
		No consensus	$n = 0/6$	0.5%-110%	3%	$n = 2/7$	1%-9%
		0.19-0.25 cm/HU	$n = 1/1$		2.8-4.4 cm/HU	$n = 1/1$	
					Various	$n = 2/2$	
					0.91	$n = 1/1$	
					7 lp groups	$n = 1/1$	
Pixel signal value/HU calibration	50 HU	40 HU	$n = 7/14$	18-50 HU	50 HU	$n = 9/14$	20-100 HU
		1%	$n = 1/1$		1.25%	$n = 1/1$	
		0.19-0.25 cm/HU	$n = 1/1$				
		Baseline	$n = 1/1$				
					Various	$n = 1/1$	
					3% contrast for SFOV HU	$n = 1/1$	
Image scaling and orientation	1 mm over 100 mm	0.5 mm ($n = 6/15$), 1 mm ($n = 5/15$)		0.05-2 mm	1 mm	$n = 14/22$	0.1-2 mm
	Correct orientation	10 HU	$n = 1/1$				
		1.5%	$n = 2/2$		No consensus	$n = 0/2$	2%-3%
		1(3 for long)	$n = 1/1$				
					Various	$n = 1/1$	
HU uniformity	[d]	30 HU ($n = 3/13$), 40 HU ($n = 4/13$)		1-65 HU	30HU ($n = 4/16$), 40 HU ($n = 4/16$)		1.5-100 HU
		No consensus	$n = 0/4$	1.5%-98%	No consensus	$n = 0/6$	1.5%-97%
		Centre ± 40 HU	$n = 2/3$	Centre ± 20HU—40HU			
		Compared to baseline	$n = 1/1$				
Room lasers							
Alignment of wall and overhead lasers		1 mm	$n = 15/29$	0.5-3 mm	2 mm	$n = 22/34$	1-5 mm
Alignment of isocentre wall lasers with additional lower lasers (eg, lasers 20 cm below isocentre)		1 mm	$n = 6/9$	1-2 mm	2 mm	$n = 7/11$	0.5-3 mm
Interlocks							
Radiation protection survey		Unacceptable	$n = 1/1$				
		0.15μSv/hr	$n = 1/1$		7.5 μSv/hr	$n = 2/2$	
		Difference from reference	$n = 1/1$				
		Significant change 10%	$n = 1/1$				

(continued)

Table 4. (continued)

QC Test	IPEM Report 81 (2018) Action[5]	Notification			Suspension		
		Most Frequent Answer (Mode)		Range	Most Frequent Answer (Mode)		Range
Maze entrance	Functional	Functional	$n = 11/11$		Functional	$n = 21/21$	
Audio-visual monitors	Functional	Functional	$n = 10/10$		Functional	$n = 21/21$	
		Poor but usable quality	$n = 1/1$				
Beam on indicator	Functional	Functional	$n = 12/12$		Functional	$n = 19/19$	
Beam termination	Functional	Functional	$n = 11/11$		Functional	$n = 20/20$	
Backup MU counter	Functional	Functional	$n = 7/7$		Functional	$n = 12/12$	
		1 MU	$n = 3/3$		1 MU	$n = 2/6$	0-3 MU
		1%	$n = 1/1$		2%	$n = 3/3$	
Couch collision	Functional	Functional	$n = 6/6$		Functional	$n = 11/11$	
Gantry collision	Functional	Functional	$n = 9/9$		Functional	$n = 15/15$	

$n = x/y$ where x is the number of centres reporting modal value and y is the number of centres who responded to the question in the stated units.
[a]0.5% variation between independent measurements and 1% from reference value.
[b]The survey question was ambiguous as to whether "through leaves" meant "between leaves" or "below leaves" and centres may have answered differently.
[c]No unexpected image artefacts/no uncorrected defective pixels.
[d]Manufacturer spec. consistent with commissioning.
[e]2 mm over 100 m should be achievable.
[f]Within specification.
CBCT, cone beam computed tomography; DMLC, dynamic multi leaf collimator; DRGS, dose rate gantry speed; F&S, flatness and symmetry; FFF, flattening filter free; FSD, focus to skin distance; HU, Hounsfield unit; kV, kilo voltage; MLC, multileaf collimator; MU, monitor unit; MV, megavoltage; PDD, percentage depth dose; SABR, stereotactic body radiation therapy; SRS, stereotactic radiosurgery; TPR, tissue phantom ratio; VMAT, volumetric modulated arc therapy.

Medical, Melbourne, United States) (23%). 91% stated gamma criteria is used for measured PSQC 60% of which stated 3%/3 mm >95% is used as the passing tolerance, it was not always specified whether this was using local or global normalization. SABR/SRS tolerances were typically tighter and more variable between centres, but modal response was 3%/2 mm with no specified pass percentage, and again was unclear whether this was using local or global normalization. For point dose measurements the most common pass criteria was 3% plan dose and 5% per beam. 60% stated that they deliver a set of reference plans for PSQC with centres most commonly stating they perform these checks monthly or 6 weekly. 23% stated they do not perform these plans and 2% stated they were planning on introducing it.

Failing measured PSQC results would have a review by an MPE in 91% of centres, with 35% stating they would consider a replan and 28% would remeasure often stating by an independent operator and on a different linac. Other common responses included, involving a clinician (19%) and relaxing tolerances (9%). However, 23% of centres reported zero plans are replanned per year due to failing measured PSQC results and a further 44% stated ≤5 plans per year. Other centres stated qualitatively very low or <1%. Three centres reported higher frequencies of replanning as a result of failed measurements:<5% (of 300-400 plans), 12 plans/year and 18 plans/year. Clinical scientists were the most common staff group to perform PSQC (63% of responding centres). 7% stated radiographers perform the portal dosimetry measurements.

In vivo measurements were performed in 58% of centres. EPID panel was used in 37% of centres, entrance diodes in 30% and TLDs in 12%. Common reasons given by centres who do not perform *in vivo* measurements included; diodes being phased out, false negative/positive rate too high, rely on imaging instead, diodes not appropriate for VMAT techniques, risk assessments indicated able to reduce, rely on PSQC and routine QC instead. 14% stated that while they do not currently perform *in vivo* measurements they are in the process of commissioning EPID dosimetry.

End to end tests were performed in 49% of centres with 21% clarifying these are performed as part of commissioning new techniques/equipment/class solutions, after upgrades or during external audits. Only 5% stated they are routinely performed annually and 2% stated monthly.

Discussion

QC management

Table 1 indicates a shift towards more QC being performed outside of normal working hours (09:00-17:30) compared to the 2012 survey. Previously, 30% of centres performed all QC during the normal day,[4] which is now only undertaken in 12% of centres. Table 2 highlights a large range in the time required for performing linac QC which potentially indicates large variations in the quantity, complexity, or efficiency of QC tasks between centres but could also be a result of some centres including daily run up tasks in this number. Table 2 shows a large difference between the time required to perform QC of c-arm gantry linacs compared to ring gantry linacs, with the former reported to take twice as long (median values).

Nearly all QC schedules, 91%, were found to be derived from IPEM Report 81 (2018)[5] with changes based upon a centres own experience in 67% of cases. 100% of centres cited IPEM Report 81 (1999)[2] in the previous survey and 54% stated machine reliability and historic data, suggesting an increased variation between centres. Interestingly, both surveys had only 7% of centres stating they use FMEA, indicating minimal uptake of the previous survey's recommendation to move to more considered design of QC schedules. However, IPEM Report 81 (2018)[5] was published after the publication of the previous survey and therefore would imply that these IPEM Report 81 (2018)[5] recommendations take into account the risks of not performing QC at the specified frequency and take precedence over the previous survey recommendations. This is a likely case why few centres have adopted the FMEA approach. If a full FMEA study on linac QC became available and was supported in the same way as IPEM publications, it is possible we would see more of a shift to that approach of QC. Previously, 37% of centres mentioned near misses informed schedules compared to only 5% in this survey. 20% of centres previously said the plan-do-study-act cycle, no centres reported that in this survey.

There was consistency in when centres last performed a review of their QC schedule, with 56% stating within the last year for this survey compared to 54% in the previous survey. Five centres reported they had not completed a review since the publication of IPEM Report 81 (2018),[5] the most recent UK guidance. The most reported changes made as a result of reviewing QC schedules were found to be changes in QC frequency and tolerance, not a complete redesign. This is reflected in minimal deviation from an IPEM Report 81 (2018)[5] approach. This could explain why despite high rates of recent review, 51% of centres still responded "Yes" when asked if they believe their QC schedule is in need of a review and update, compared to only 33% of centres in the previous survey.[4] This is supported with 9% of centres reporting they wish to introduce more automated QC, 7% reporting they wish to introduce uncertainty models and 5% wishing to move to paperless QC. The desire to overhaul the QC approach has existed since the previous survey but this has not yet been achieved by most centres.

Just over a quarter of centres reported using QATrack+ for QC record keeping (ceased maintenance from January 2025, after data collection completed). Only a few centres reported using paper methods, citing funding as an issue in making the transition to electronic recording.

Compared to the previous survey results[4] there has been an improvement in the number of centres achieving 100% of monthly QC completion, previously <30% but now 47%. However, more centres reported less than 80% of monthly QC achieved, previously 4% but now 9%.

QC frequency

A similar number of centres reported the use of risk assessments to determine QC in this survey (26%) compared to the previous survey (30%). 7% of centres also specified that the frequency of QC performed was based upon what was practicably achievable, this highlights the conflicting demands radiotherapy departments face. 16% of centres stated that they were unable to review the frequency of QC due to such demands. This highlights a circular problem; radiotherapy departments may be too busy to improve efficiency which in turn results in inefficiency. Some centres mentioned an apprehension of reducing tolerances below IPEM Report 81 (2018)[5] or have not seen a need to. This is reflected in

Table 3 where typically centres are performing tests at least as frequently as IPEM Report 81 (2018)[5] recommends. Outliers are largely electron tests, for example, electron energy ratio at different gantry angles, linearity of dose with MU, and constancy of dose output QC are no longer being performed in 44%, 28%, and 26% of centres respectively, a reduction in frequency from IPEM Report 81(2018)[5] recommendations.

The frequency at which centres reported performing TPR20:10 has also decreased below previous survey results, 74% of responding centres,[4] to a bimodal split between monthly (30%) and annually (30%). Standard output was recommended to be performed monthly in IPEM Report 81 (2018)[5] and found to be performed monthly in 52% of centres in the previous survey and monthly in 58% in the current survey. Weekly output was still performed in 26% of centres in the current survey. However, all centres perform daily output constancy checks, 40% with a manufacturer-integrated device and 67% with an external device.

There was good consistency across the UK for many QC tests, such as for c-arm gantry quick checks of beam flatness and symmetry performed daily and more comprehensive tests performed monthly, for almost all responding centres. The prevalence of devices for quick checks and integration with linac automated QC tools may explain the ability to move to daily checks even though this was recommended as a monthly test in IPEM Report 81 (2018).[5]

There was a lower level of consistency for QC tests of imaging systems, such as for 3D kV imaging where equal proportion of centres measured at monthly, quarterly, and 6 monthly, as well as intermediate periods.

QC tolerances

It was common in the survey results for the IPEM Report 81 (2018)[5] published "action levels" to be used to set local suspension levels, with lower notification levels derived from centre experience. "Action levels" are defined to be equivalent to what this survey refers to as notification levels. Centres are therefore commonly implementing tighter tolerances than the IPEM Report 81 (2018) guidance[5] may suggest. For example, there has been tightening of some tolerances of fundamental QC results, such as standard output measurement. The modal notification tolerance was 1.5% (at 16 of 37 centres responding in %) compared to 2% guideline in IPEM Report 81 (2018).[5] This reflects a drive for improved accuracy in treatment and the technical equipment to maintain performance at this level. The suspension level for standard output remains at 2% in the majority of centres. There has been little published linking tolerances to clinical outcomes, although Bolt et al[9] in a study of output measurements in all UK radiotherapy centres over a 6-month period suggested a tightening of tolerance levels may lead to improvements in tumour control probabilities.[9]

No consensus of the naming convention of notification and suspension level tests was found with action being the most common term for both levels, there is a risk this could result in confusion between centres. Therefore, a suggestion of this survey is for centres to adopt "notification" and "suspension" definitions, this is in line with recommendations from the UK kV Survey conducted in 2024.[10]

The least consensus for c-arm linac QC was reported for tolerance levels of imaging QC tests, due in part to different measurement methods and measurement units, and likely a lack of guidance in publications. A quarter of centres have separate radiation protection or diagnostic departments perform the annual imaging QC tests which could also be contributing to the difference in types of imaging tests performed and their tolerances.

Ancillary equipment

Ancillary equipment has potential to directly affect patient treatment, and as such has comparable status to linac performance. Little consensus was found for gating implementation, although monthly or less frequent QC was reported.

The frequency at which diode calibration check is performed has not changed since the previous survey with 17% of centres stating it is performed monthly previously compared to 19% in this survey (Table S7). This is interesting as it appeared that the use of diode measurements were being reduced from centres responses to PSQC questions yet the percentage of centres performing this check monthly has remained constant.

Tolerances for linac ancillary equipment, in particular gating and surface guided equipment, showed ranges with a 10-fold difference (Table S8). In room respiratory monitoring system 0.2-2 mm notification, 0.3-3 mm suspension, temporal accuracy 0.1-1 second notification, and stability 0.2-2 mm suspension. This could be because these are relative new technologies and consensus methodologies have not yet been established.

Patient-specific quality control

There was a lack of consistency in the type and quantity of patient-specific quality control (PSQC) performed at centres across the UK. PSQC testing may be interpreted as calculations independent of the treatment planning system used for the plan creation or physical dosimetric measurements made prior to treatment commencement.

Most centres said they would consider a replan if failing PSQC measurements occurred, yet this translated to very few actual replans; almost 70% of centres replanned between 0 and 5 plans per year. It is unclear whether this is a result of very few plans failing measurement or from MPE decision to proceed to treatment with the original plan. The survey did not ask the percentage of plans that fail PSQC per year. Two of the three centres that stated a much higher percentage of replans in comparison to the rest of the cohort also reported a much higher percentage of the number that are measured. This indicates an inconsistent approach to PSQC which may have significant impact on the clinical workload.

Conclusions

The linac QC survey was sent to all UK radiotherapy centres with 63% responding ($n = 43/68$). This has provided an update to the UK consensus practice of linear accelerator QC. Topics covered were c-arm linacs, ring gantry linacs as well as linac ancillary equipment and PSQC, which have not previously been surveyed in the UK on this scale. Findings include that among the main stated reasons QC is undertaken is to "demonstrate safe use." Almost all centres stated IPEM Report 81 (2018)[5] as a main source or starting point to structure their QC schedules including tolerances and frequency with adjustments based upon local experience, evolution of clinical techniques and available QC equipment.

This work is not intended to be used as professional advice but to offer an update to the previous review of consensus practice in the UK.

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Supplementary material

Supplementary material is available at *BJR* online.

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Conflicts of interest

None declared.

References

1. UK Statutory Instruments. *Ionising Radiation (Medical Exposure) (Amendment) Regulations 2024*. Accessed March 31, 2025. www.legislation.gov.uk
2. Mayles WPM, Lake R, McKenzie A, et al. *Physics Aspects of Quality Control in Radiotherapy. IPEM Report 81*. 1st ed. Institute of Physics and Engineering in Medicine; 1999.
3. Venables K, Winfield E, Deighton A, Aird E, Hoskin P. A survey of radiotherapy quality control practice in the United Kingdom for the START trial. *Radiother Oncol*. 2001;60:311-318.
4. Palmer AL, Kearton J, Hayman O. A survey of the practice and management of radiotherapy linear accelerator quality control in the UK. *Br J Radiol*. 2012;85:e1067-e1073. https://doi.org/10.1259/bjr/46195110
5. Patel I, Weston S, Palmer AL, et al. *Physics Aspects of Quality Control in Radiotherapy, IPEM Report 81*. 2nd ed. Institute of Physics and Engineering in Medicine; 2018.
6. Klein E, Hanley J, Bayouth J, et al. AAPM task group report 142. Quality assurance of medical accelerators. *Med Phys*. 2009;36:1125-1148. https://doi.org/10.1118/1.3082195
7. Al-Hallaq HA, Cerviño L, Gutierrez AN, et al. AAPM task group report 302: surface-guided radiotherapy. *Med Phys*. 2022;49:e82-e112. https://doi.org/10.1002/mp.15532
8. Court L, Balter P, Gao S, et al. Experience and Suggestions on "Commissioning and QA Procedures" for Halcyon [online]. MD Anderson Cancer Centre and University of Pennsylvania. Accessed March 31, 2025. mediaroom.com.
9. Bolt M, Clark CH, Nisbet A, Chen T. Quantification of the uncertainties within the radiotherapy dosimetry chain and their impact on tumour control. *Phys Imaging Radiat Oncol*. 2021;19:33-38. https://doi.org/10.1016/j.phro.2021.06.004
10. Palmer AL, Brimelow J, Downes P, et al. A review of kilovoltage radiotherapy treatment in the United Kingdom: quality control, radiation dosimetry, treatment equipment, and workload. *Br J Radiol*. 2025;98:392-403. https://doi.org/10.1093/bjr/tqaf001

British Journal of Radiology, 2025, 98, 1463–1482
https://doi.org/10.1093/bjr/tqaf140
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References:
1. Gacci M et al. Bladder Instillation Therapy with Hyaluronic Acid and Chondroitin Sulphate Improves Symptoms of Postradiation Cystitis: Prospective Pilot Study. Clin Genitourin Cancer 2016; Oct;14(5):444-449. 2. Giannessi C et al. Nocturia Related to Post Radiation Bladder Pain can be Improved by Hyaluronic Acid Chondroitin Sulfate (iAluRil). Euro Urol Suppl 2014; 13: e592. 3. UK IQVIA data (accessed August 2024)

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