

# A survey of quality control practices for high dose rate (HDR) and pulsed dose rate (PDR) brachytherapy in the United Kingdom

Antony L. Palmer, MSc<sup>1,2</sup>, Margaret Bidmead, MSc<sup>3</sup>, Andrew Nisbet, PhD<sup>1,4</sup>

<sup>1</sup>Department of Physics, Faculty of Engineering and Physical Science, University of Surrey, Guildford, GU2 7XH, UK, <sup>2</sup>Medical Physics Department, Queen Alexandra Hospital, Portsmouth Hospitals NHS Trust, Portsmouth, PO6 3LY, UK, <sup>3</sup>Medical Physics Department, The Royal Marsden NHS Foundation Trust, London, SW3 6JJ, UK, <sup>4</sup>Medical Physics Department, Royal Surrey County Hospital NHS Foundation Trust, Guildford, UK

## Abstract

**Purpose:** A survey of quality control (QC) currently undertaken in UK radiotherapy centres for high dose rate (HDR) and pulsed dose rate (PDR) brachytherapy has been conducted. The purpose was to benchmark current accepted practice of tests, frequencies and tolerances to assure acceptable HDR/PDR equipment performance. It is 20 years since a similar survey was conducted in the UK and the current review is timed to coincide with a revision of the IPEM Report 81 guidelines for quality control in radiotherapy.

**Material and methods:** All radiotherapy centres in the UK were invited by email to complete a comprehensive questionnaire on their current brachytherapy QC practice, including: equipment type, patient workload, source calibration method, level of image guidance for planning, prescribing practices, QC tests, method used, staff involved, test frequencies, and acceptable tolerance limits.

**Results:** Survey data was acquired between June and August 2012. Of the 64 centres invited, 47 (73%) responded, with 31 centres having brachytherapy equipment (3 PDR) and fully completing the survey, 13 reporting no HDR/PDR brachytherapy, and 3 intending to commence HDR brachytherapy in the near future. All centres had comprehensive QC schedules in place and there was general agreement on key test frequencies and tolerances. Greatest discord was whether source strength for treatment planning should be derived from measurement, as at 58% of centres, or from the certified value, at 42%. IPEM Report 81 continues to be the most frequently cited source of QC guidance, followed by ESTRO Booklet No. 8.

**Conclusions:** A comprehensive survey of QC practices for HDR/PDR brachytherapy in UK has been conducted. This is a useful reference to which centres may benchmark their own practice. However, individuals should take a risk-assessment based approach, employing full knowledge of local equipment, clinical procedures and available test equipment in order to determine individual QC needs.

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**Key words:** high dose rate (HDR), brachytherapy, quality control (QC), quality assurance (QA), survey.

## Purpose

The dosimetric accuracy of brachytherapy delivery is fundamental to the achievement of clinical treatment aims, tumour control and minimised normal tissue toxicity. As early as 1993 Van Dyk *et al.* [1] defined a requirement for brachytherapy treatment delivery of 3% accuracy in dose at distances of 0.5 cm or more at any point for any radiation source. Control of dose delivery is particularly difficult to achieve in brachytherapy due to small treatment distances, very high dose gradients and a multitude of aspects that affect accuracy [2]. A quality assurance system in radio-

therapy is essential to ensure treatment delivery is consistent and as intended. This will include a multitude of quality control (QC) tests designed to evaluate actual operating performance in comparison to goal values and to enable rectification/reconciliation of any differences.

Brachytherapy is currently undergoing a period of significant innovation and rapid modernisation [3], including a shift from 2D to 3D basis [4], the enhanced use of imaging [5], patient-specific treatment plan optimisation, fully volume-based prescribing [6], inverse-planning [7], advanced planning algorithms [8], use of advanced treatment applicators [9,10], and *in-vivo* dosimetry verification systems

**Address for correspondence:** Antony L. Palmer, Medical Physics Department (Radiotherapy Physics), F-Level, Queen Alexandra Hospital, Portsmouth, PO6 3LY, UK,  
✉ e-mail: antony.palmer@porthosp.nhs.uk

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[11]. It is essential that QC test schedules keep pace with the changing technology and clinical practice. This includes re-assessing the use of historic QC tests that are no longer fit for purpose and replacing with more relevant QC, or where system performance is verified by other means avoiding unnecessary redundancy.

Quality assurance of all brachytherapy techniques has recently received increased attention following low dose rate brachytherapy incident in 2009 at the Philadelphia VA Medical Centre in which a number of patients received poor quality prostate seed brachytherapy treatment [12]. There have also been errors in brachytherapy due to confusion of source strength units, including incorrect entry into treatment planning systems [13]. In addition, there are numerous publications on more subtle equipment-related quality issues in high dose rate (HDR) delivery, such as unexpected, irregular spacing of source dwell positions in ring applicators [14]. It is important that QC testing is robust and comprehensive and meets the needs of modern equipment and treatment techniques.

It is over twenty years since a comprehensive assessment has been undertaken of brachytherapy QC practice in the United Kingdom (UK): reproduced in the Institute of Physics and Engineering in Medicine (IPeM) Report 81 [15]. The IPeM guidance on QC for radiotherapy is currently being revised, and it is therefore timely to undertake a repeat benchmark exercise of current QC practice for brachytherapy. The present survey has been endorsed by the IPeM Radiotherapy Special Interest Group. A similar survey was conducted in 2002 in the Netherlands and Belgium [16], which reported large variations in test frequencies and methods, and differences in QC-philosophy and available equipment. The authors are unaware of any contemporary comparisons of brachytherapy QC practice.

The publication of a comprehensive assessment of current QC practice has several potential benefits for individual radiotherapy departments: centres may be reassured that their QC systems are in-line with accepted practice; alternatively, centres may identify discrepancies against standards of practice. Following investigation, this may lead to either reduction of tests or frequencies and hence efficiency savings, or resolution of deficiencies and potential improvements in safety and quality. However, the details of QC tests presented here should not be interpreted as guidelines or recommendations, but as a 'snapshot' of current UK practice. It is important to be aware that specific QC testing is a local decision, based on many local factors, and should ideally be based on risk-assessment approaches.

## Material and methods

All 64 radiotherapy centres in the UK were contacted by email in June 2012 to request their contribution to the study, with collation of responses taking place during June to August 2012. Centres were asked to complete a detailed questionnaire on their routine QC practices and other aspects of HDR and PDR service provision. To enable a contextual review of QC practice, initial questions were asked included equipment type, average patient workload, sites treated, source strength calibration methods, level of image

guidance, and prescribing practice. A spreadsheet containing a comprehensive list of possible quality control tests for treatment and planning equipment was also provided. Centres were asked to document whether they routinely perform each test, at what frequency, by which staff group, and the acceptable tolerance values used. They were also asked to comment whether the target test frequencies were actually achieved in practice.

## Results

### *Equipment profile and general physics aspects of brachytherapy service*

Forty-seven (73%) of the 64 UK radiotherapy centres that were invited to take part in the survey of HDR and PDR QC responded. Thirty-one centres had appropriate brachytherapy equipment and provided fully completed questionnaires on their QC practice. Thirteen centres reported no HDR or PDR brachytherapy facilities, and further 3 intended to commence HDR brachytherapy in the near future. The majority (29) of radiotherapy centres had HDR units, with only three having access to PDR treatments, two having exclusively PDR. The equipment profile of the responding centres included 20 Nucletron/Elekta microSelectron, 7 Varian GammaMed, 4 Nucletron/Elekta/Isodose Control Flexitron, 1 Eckert & Ziegler Bebig HDR Multisource, and 1 Varian Varisource. One centre had 3 treatment units, 1 HDR and 2 PDR, all others had 1 unit. One centre had a Co-60 source (HDR), the others were all using Ir-192. The latter isotope being exchanged at 3-monthly intervals in all but two centres: one at 4-monthly intervals and another PDR centre at between 3 and 6 months. One centre stated they were considering moving to 4-monthly intervals to reduce cost. The planned frequency of exchange for the Co-60 source was 4 years. The mean number of HDR fractions delivered per year at each centre was 281, with interquartile range 173 to 359 (minimum 80 and maximum 730).

There was a lack of agreement as to whether the locally measured value or the manufacturer's supplied source certificate should be used for the source strength value in treatment planning calculations; 18 centres (58%) preferring to use their own measurement. The current UK Code of Practice for HDR brachytherapy dosimetry [5] recommends a well chamber for the primary source strength measurement, but allows some flexibility in the method used to obtain the second independent verification value. Table 1 lists methods used for source calibration and their relative popularity within UK centres.

The quoted origin of the TG-43 [18] source model data used in the treatment planning systems also varied between centres. Fourteen (45%) used the supplied manufacturer data, 8 (26%) used journal published data, and 8 (26%) used manufacturer data and verified this against publications (with 1 (3%) not answering the question). There was also a variety of methods quoted as an independent check of the output of the treatment planning system. The methods and their popularity are given in Table 2.

Treatment plan optimisation in some form was used in 23 centres (73%), including for cervix (majority), prostate (next most common), skin/limb moulds, interstitial anus,

**Table 1.** Methods employed and their popularity, for source strength measurement of HDR & PDR sources at centres in UK

Technique for determination of source strength		Number of centres	Percentage of centres
Initial method	Well chamber	29	94
	Manufacturer supplied source certificate	1	3
	NE2571 chamber with in-air jig	1	3
Verification method	Well chamber (second unit)	14	45
	NE2571 chamber with in-air jig	12	39
	NE2571 chamber in solid phantom	2	6
	Manufacturer supplied source certificate	1	3
	I-125 seed device with adaptor	1	3
	Gafchromic film calibrated via 260kV X-rays	1	3

**Table 2.** Methods employed and their popularity, to independently verify treatment planning system (TPS) calculations at centres in UK

Technique for verification of TPS calculation	Number of centres	Percentage of centres
Locally developed check software (including systems based on Matlab, Excel, Java, visual basic; usually employing either TG43 [18] or BIR/IPSM 1993 [20])	16	52
Commercial check software or additional TPS (including IMSure QA, Radcalcbrachy, Lifeline)	7	23
Manual calculation or use of data tables	3	10
Nomogram (prostate treatment) or TRAK relationship to target volume	2	6
Use of standard plans only with initial independent calculation, no per-patient plan verification	2	6
Consistency check performed with standard plan on same day	1	3

**Table 3.** Primary sources of guidance for establishing QC schedules and their popularity at centres in UK

Documents providing guidance on HDR or PDR QC	Number of centres citing document	Percentage of centres citing document
Physics aspects of quality control in radiotherapy, IPEM Report 81 [21]	19	61
A practical guide to quality control of brachytherapy equipment, ESTRO Booklet No. 8 [22]	15	48
The IPEM code of practice for the determination of the reference air kerma rate for HDR (192)Ir brachytherapy sources based on the NPL air kerma standard, 2010 [17]	10	32
Code of practice for brachytherapy physics, AAPM TG-56, 1997 [23]	8	26
Discussion with colleagues and other centres' documents	6	19
High dose-rate brachytherapy treatment delivery, AAPM TG-59, 1998 [24]	4	13
Recommendations for Brachytherapy Dosimetry, BIR/IPSM Report 1993 [20]	3	10
Calibration of photon and beta ray sources used in brachytherapy, IAEA TecDoc 1274, 2002 [25]	3	10
Quality assurance for clinical radiotherapy treatment planning, AAPM TG-53, 1998 [26]	2	6
Quality assurance tests for prostate brachytherapy ultrasound systems, AAPM TG-128, 2008 [27]	2	6
Manufacturer's guidance or manual	2	6
A revised AAPM protocol for brachytherapy dose calculations, AAPM TG-43U1, 2004 [18]	2	6
Thomadsen BR 'Achieving quality in brachytherapy', 1999 [28]	2	6
Other radiotherapy or brachytherapy text books, each $n = 1$	2	6
Remote afterloading technology, AAPM TG-41, 1993 [29]	1	3
Towards Safer Radiotherapy, joint report of RCR, SoR, CoR, IPEM, NPSA, BIR, 2008 [30]	1	3
In-house experience with treatment unit	1	3
Quoted 'Relevant regulations'	1	3
Quoted 'Unsure of origin'	1	3

vaginal vault, lung, head & neck, multilumen mammosite breast, intraluminal, and keloid scars. Twenty-seven centres (87%) optimised treatment plans for individual patients; 19 (61%) employing manual methods and the others inverse planning optimisation, often with final manual adjustment. 6 centres (19%) stated they used pre-optimised standard plan libraries.

The level of image-guidance varied significantly between centres. In cervix treatments, 16 (52%) used CT alone for treatment planning, 12 (39%) MRI with CT, 2 (6%) MRI alone, and 1 (3%) c-arm 2D imaging alone. When MRI was available this was often used for the first fraction, with CT used in subsequent treatments. For vaginal vault treatments, 13 (42%) did not image, 10 (32%) used orthogonal 2D X-ray, and 8 (26%) used CT. Some centres responded they would only image vault treatments for complex cases or if individualised plans were required. There were an insufficient number of responses on imaging used for other treatment sites for statistical significance.

Gynaecology cancers were the most commonly treated. In cervix, 22 centres (71%) still prescribe treatment doses to Manchester Point A. For those prescribing instead to high-risk clinical target volume, HR-CTV [19], all centres additionally record the Point A dose. Only 2 centres (6%) exclusively recorded ICRU organ at risk (OAR) point doses, likely when only orthogonal imaging is used, the others recorded either just GEC-ESTRO dose-volume histogram (DVH) data (48%), or both ICRU point dose and DVH data (46%).

Centres were asked to list the primary sources of guidance used in establishing their HDR or PDR quality control schedules. Table 3 provides a list of the documents that were indicated and their popularity, quoted as the percentage of centres citing the document. All centres stated they had reviewed the content of their HDR/PDR QC schedule within the last two years, except two which did not answer the question.

### Quality control tests

Table 4 provides detail from the HDR and PDR QC survey. The table shows the percentage of centres that include each of the specific tests in their planned QC schedules. A centre is deemed to have included the test in their regular QC if it is performed within the department whether it is in the specific 'physics QC documentation' or other 'standard operating procedures', for plan checking for example. A test is deemed not to be in regular QC if it was only intended to be performed once at initial equipment commissioning. The mean and range of frequencies of testing and acceptable tolerance levels are provided in the Table. There is a significant variation in consistency between centres across the range of tests. Inclusion of tests in QC schedules varies from 31 centres (100%) for source strength measurements to just 2 centres (6%) for MRI tests, the latter of course being due to limitations of access to MRI for brachytherapy-specific clinical use and QC testing (it was not recorded how many centres routinely used MRI for brachytherapy planning). The consistency of frequency of testing and acceptable tolerance levels also varies markedly between the individual QC tests, between complete or lack of agreement for specific tests. Of the 45 tests includ-

ed in the survey, 21 were performed at greater than 75% of centres, and 4 were performed at less than 25% of centres. There were no significant differences in the QC techniques employed for HDR and PDR equipment, and certainly within the range of practice between centres. Only 2 centres (6%) reported achieved measurement frequencies were below planned measurement frequencies, and then only for up to two tests each.

Table 5 documents additional QC tests suggested by responding centres, which were not included in the original list of tests in the distributed survey. These are generally proposals made by single centres and there is no information of the popularity of these tests across UK, however they are included for interest.

Quality control testing of dosimetry equipment associated with HDR and PDR use has not been included in the results tables; secondary standard calibrations and consistency testing of well chambers and Farmer-type ionisation chambers, which are covered elsewhere and in published codes of practice [17].

### Discussion

The survey data presented in this report represents the current practice in the majority of brachytherapy centres within the UK. Whilst there is a high level of consistency in inclusion, frequency and tolerance values for some tests, such as source strength measurement, there are varied responses to other tests. This is likely due to differences in local planning and treatment procedures in clinical use, availability of equipment, and differing functionality or performance of equipment. Local assessment of QC needs is essential in determining schedules, rather than simple reliance on the 'majority view'. However, benchmarking against accepted practice is a good starting point for local review. A risk assessment approach including local known factors is advocated for final decisions on QC testing. All schedules must include measurement of source strength, source position and dwell time, but the specific details require knowledge of local clinical practice and equipment in use.

While there was some variation in staff groups involved in QC testing between centres, physics staff most commonly performed all of the QC tests except facilities testing (Table 4) which was almost exclusively performed by radiographers. Within each centre, a specific QC test may be performed in multiple ways, including staff group involved, equipment used, frequency of measurement, and tolerance value. Each different measurement method has been included in the results table. For example, 'decay correction accuracy at treatment unit' may be performed prior to each patient treatment by radiographers, and separately by radiotherapy physics after each source change, but to a tighter investigation tolerance level. The achievable tolerance value for this test is also dependent on the equipment design, whether the software makes hourly corrections for source decay or 12-hourly for example. The standard operating procedures of individual departments also have a significant affect on the QC testing that is performed. This includes all aspects such as whether optimised or standard/tabulated planning is used, whether 2D or 3D imaging is utilised, and whether electronic transfer of data is available. An independent method for the verification of the accuracy of treat-

**Table 4.** HDR & PDR QC survey: response to questionnaire on test popularity, measurement frequency and tolerance values

QC test	% of centres including in routine QC	Measurement intervals % using mean value (and range of responses)	Tolerance % using mean value (and range of responses)	Comments	
Source strength	Initial measurement after source installation	100	100% at <b>source change</b> (all centres)	52% use <b>3%</b> (2% to 5%)	Achievable tolerance depends on test method and whether result is compared to certificate or 1 <sup>st</sup> measurement
	Independent measurement after source installation	100	100% at <b>source change</b> (all centres)	35% use <b>3%</b> (0.5% to 5%)	
	Repeat measurements during life of source	75	83% at <b>1 m</b> (1 d to 1 m)	56% use <b>3%</b> (0.5% to 5%)	
	Leak testing of source	97	97% at <b>source change</b> (1 m to source change)	71% <b>not &gt; background</b> (zero to 200 Bq)	
Treatment unit function	Confirm accuracy of source data at treatment unit	97	41% at <b>each patient</b> (each patient to commissioning only)	55% use <b>exact match</b> (exact to 4%)	Tolerance depends on how frequently unit makes decay correction  Some standard template plans not electronically transferred  May be independent test or combined
	Confirm accuracy of decay correction at treatment unit for plans	91	86% at <b>each patient</b> (weekly to commissioning only)	22% use <b>1%</b> (exact match to 3%)	
	Plan data transfer from TPS	83	96% at <b>each patient</b> (weekly to commissioning only)	63% use <b>exact match</b> (0.1 s to 2%)	
	Simulated treatment functionality test	68	68% at <b>1 d</b> (1 d to 12 m)	50% use <b>1 mm</b> (1 mm to 2 mm)	
	System display and print-out accurate and in agreement	96	83% at <b>each patient</b> (each patient to commissioning only)	88% use <b>exact match</b> (exact to 2%)	
	Test of function with mains power loss	58	50% at <b>3 m</b> (1 m to 12 m)		
	Test of uninterruptable power supply (UPS)	44	31% at <b>3 m</b> (1 d to 12 m)		
Applicators, source position and source movement	Visual inspection of applicators and transfer tubes for damage	97	70% at <b>1 d</b> (1 d to 12 m)		Often rely on image match to TPS library  Most commonly only when suspected damage  Large variation in definition of test methodology  Multiple techniques often in use at each centre  Absence of test often due to ring applicator not being used  Absence of test normally due to marker wire not being used  Not commonly in use in UK
	Measurement of dimensions and angles of applicators and transfer tubes	48	46% at <b>commissioning</b> (each patient to 12 m)	75% use <b>1 mm</b> (0.5 mm to 1 mm)	
	X-ray imaging of applicators	32	64% at <b>commissioning</b> (3 m to 12 m)	100% use <b>1 mm</b>	
	Verification of source dwell timer accuracy	97	38% at <b>1 d</b> (1 d to 12 m)	38% use <b>1 s</b> (0.1 s to 2 s)	
	Measurement of source dwell positions in straight catheter (not clinical applicator)	100	42% at <b>1 d</b> (1 d to 4 m)	78% use <b>1 mm</b> (0.5 mm to 2 mm)	
	Measurement of source dwell positions in clinical applicators	55	36% at <b>commissioning</b> (2 w to 12 m)	79% use <b>1 mm</b> (1 mm to 2 mm)	
	Measurement of actual source dwell positions compared to TPS stated position in complex geometry e.g. ring applicator	41	35% at <b>3 m</b> (2 w to commissioning)	67% use <b>1 mm</b> (1 mm to 3 mm)	
	Source position relative to dummy source or marker wire	60	35% at <b>commissioning</b> (1 d to 12 m)	72% use <b>1 mm</b> (0.5 mm to 2 mm)	
	Applicator/transfer tube connection interlock and simulated error	73	68% at <b>1 d</b> (1 d to 6 m)		
	Verification of expected position of internal applicator shielding	15	50% at <b>each patient</b> (each patient to commissioning)		

Table 4. Cont.

QC test	% of centres including in routine QC	Measurement intervals % using mean value (and range of responses)	Tolerance % using mean value (and range of responses)	Comments	
Measurement of source transit times	47	41% at <b>3 m</b> (1 w to commissioning)	No consistency, responses were: 0.1 s, < 0.5 s, < 1 s, not > baseline, not > 0.05 s dwell equivalent	Large variety of techniques (well chamber to stop watch) and tolerance values	
Confirm error code 'meanings and actions' are available at treatment unit	36	25% each at 1 d and 12 m (1 d to commissioning)		Historic test, mostly replaced with improved software interface information	
Radiation monitor of applicators after use	26	86% at <b>each patient</b> (each patient to 1 w)	100% <b>not above background</b>	Majority rely on in-room radiation monitor	
Treatment planning system	Accuracy of source model data used by TPS (e.g. check TG-43 data against reference values)	36	65% at <b>commissioning</b> (1 m to commissioning)	No consistency (interpolation to 5%)	Normally undertaken at software updates
	Accuracy of individual source data used by TPS (e.g. source strength, calibration date)	89	64% at <b>each patient</b> (each patient to 3 m)	No consistency, responses were: exact match, rounding error, 1 day correction, 0.5%, 1%, 2%, 3%	Tolerance may depend on how frequently unit makes decay correction
	Calculation of standard plans compared to reference data	63	28% at <b>3 m</b> (1 d to commissioning)	No consistency, responses were: exact match, 1%, 2%, 3%, 5%, 1 mm isodose lines	
	Independent check calculation of TPS patient plans or standard plans	62	74% at <b>each patient</b> (each patient to commissioning)	50% use <b>3%</b> (1% to 5%)	Depends whether patient-specific optimised or standard plans are in use
	Repeat of tests performed at TPS commissioning (e.g. DVH accuracy, geometric tests)	32	39% at <b>3 m</b> (1 m to commissioning)	33% use <b>2 mm</b> (variety of definitions including mm, % of DVH or dose points)	Often performed at software updates only
	2D kV imaging tests, including applicator reconstruction	24	29% at <b>1 d</b> (1 d to commissioning)	50% use <b>2%</b> (1% to 2%, or 2 mm)	Absence of test often due to 2D imaging not being used
Imaging	CT imaging tests, including applicator reconstruction	38	50% at <b>commissioning</b> (each patient to commissioning)	No consistency, responses were: 1%, 2%, 3%, 5%, 1 mm, 2 mm	Absence of specific tests often due to reliance on TPS applicator library
	MR imaging tests, including applicator reconstruction and distortion	6	60% at <b>commissioning</b> (3 m to commissioning)	50% use <b>2 mm</b> (1 mm to 2 mm)	Absence of test often due to brachytherapy-specific MR imaging not being used Access to MR for QC often a problem
	Ultrasound imaging tests, including applicator reconstruction and grid alignment	26	43% at <b>3 m</b> (1 m to commissioning)	No consistency, responses were: 1 mm, 2 mm, 1 cc, 5%	Absence of test often due to ultrasound imaging not being used
	Accuracy of image data transfer to TPS	60	27% at <b>each patient</b> (each patient to commissioning)	43% use <b>exact match</b> (exact to 2 mm, or 2%)	Image-based data only
In-vivo dosimetry	Availability of <i>in-vivo</i> dosimetry system for brachytherapy?	19			Not in clinical use in the majority of centres. Included TLD, diode, MOSFET
	Calibration of <i>in-vivo</i> dosimetry system	60 (of 19)	50% at <b>1 m</b> (1 m to 'as required')	100% use <b>5%</b>	
	Test of <i>in-vivo</i> measurement against expected/planned dose measured in phantom	60% (of 19)	50% each at 1 w and 12 m	100% use <b>5%</b>	

Table 4. Cont.

QC test	% of centres including in routine QC	Measurement intervals % using mean value (and range of responses)	Tolerance % using mean value (and range of responses)	Comments
Facilities	Visual (CCTV) and audible (intercom) patient monitoring	100	93% at <b>1 d</b> (1 d to 3 m)	functional
	Radiation warning lights	100	90% at <b>1 d</b> (1 d to 4 m)	functional
	Independent radiation monitor (room monitor)	100	83% at <b>1 d</b> (1 d to 4 m)	functional
	Interlocks (e.g. door, timer delay)	100	90% at <b>1 d</b> (1 d to 4 m)	functional
	Emergency stop control	100	81% at <b>1 d</b> (1 d to 4 m)	functional
Contingencies	Practice of simulated emergency (e.g. source stuck)	97	46% at <b>12 m</b> (1 w to 12 m)	
	Presence of emergency equipment (e.g. source container, forceps, shield, monitor)	97	91% at <b>1 d</b> (1 d to 12 m)	
	Review of responsibilities (e.g. who removes applicator if source stuck)	84	50% at <b>1 d</b> (1 d to 12 m)	

*d* – day, *w* – week, *m* – month, *y* – year, *TPS* – treatment planning system

Table 5. HDR &amp; PDR QC survey: additional tests identified by responding centres, not included in original survey questionnaire

Additional possible QC tests not included in the survey	
Equipment performance	Dwell time linearity
	Check behaviour if transfer tube loop/curvature too tight
	Treatment interruption behaviour
	Source drive motor operational (check audible indication of movement)
	Satisfactory performance of system self-test
PDR	PDR pulse timing
	Check of nurses' station and remote control panels
	Catheter integrity and connectivity to PDR unit
	Partial treatment completion
TPS	Consistency of plans between software version
	Data security including backup (patient information, source data, system settings)
Imaging	Image fusion CT/MR
	MR image scaling
Radiation protection	Radiation monitoring of treatment unit (e.g. dose rate at 5 cm or 1 m)
	Radiation monitor empty treatment unit during source change
	Receipt and return of source paperwork
	Confirm controls in place for source security
Other	External audit of system quality control/performance

ment plans is required for individually-optimised treatments, but may not be required for each patient if a standard plan is used that has previously been verified and is checked for consistency.

Some tests are adopted by all centres such as 'source strength measurement' and 'source position in a straight catheter'. However, others such as 'X-ray imaging of appli-

cators' is undertaken by only 32% of centres. The difference may be attributed to whether the process is already being assessed by alternative means, and there is some evidence from the survey to support this. For applicator dimensions and angles, a specific measurement may not be necessary if the consistency of shape is evaluated through agreement to planning system library applicators used for each indi-

vidually-planned treatment (provided both physical applicator and library applicator have already been tested at commissioning). Checking of the 1<sup>st</sup> dwell position should however be verified in this case.

The number of centres including a routine measurement of actual source dwell positions in clinical applicators was surprisingly low, at 17 centres (55%). Such testing should be performed at commissioning and at regular intervals, particularly if ring applicators are in use, in which the actual and TPS planned dwell positions should be compared.

IPEM Report 81 [21] was the most frequently cited document used for guidance on required HDR or PDR QC tests, but it is surprising that only 61% of UK centres cited this document, being the UK professional body's recommendations for QC. This may be because the document is now quite dated. More recent, but again surprisingly cited by only 48% of centres is the ESTRO Booklet No. 8 [22]. There is a large range in the documents identified by individual centres as their primary sources of guidance for QC testing, supporting the need for an update of IPEM Report 81 in UK.

## Conclusions

A benchmark data set of brachytherapy HDR and PDR QC testing has been presented which is representative of practice across the UK. This updates a previous survey conducted over twenty years ago. A modern approach to QC is required to ensure continued safety and highest quality brachytherapy into the future as technology and procedures continue to increase in complexity, alongside increasing workforce pressures. QC testing schedules must be designed intelligently, including risk-based assessments of need rather than simply maintaining historic tests. The contents of this report should not be interpreted as professional advice as to the requirements of a brachytherapy QC schedule and are presented as a benchmark data set. Local decisions on QC testing must be made based on full risk-assessment and local factors.

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