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Original Research Article

National audit of a system for rectal contact brachytherapy

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ABSTRACT

Background and purpose: Contact brachytherapy is used for the treatment of early rectal cancer. An overview of the current status of quality assurance of the rectal contact brachytherapy systems in the UK, based on a national audit, was undertaken in order to assist users in optimising their own practices.
Material and methods: Four UK centres using the Papillon 50 contact brachytherapy system were audited. Measurements included beam quality, output and radiation field size and uniformity. Test frequencies and tolerances were reviewed and compared to both existing recommendations and published reviews on other kV and electronic brachytherapy systems. External validation of dosimetric measurements was provided by the National Physical Laboratory.
Results: The maximum host/audit discrepancy in beam quality determination was 6.5%; this resulted in absorbed dose variations of 0.2%. The host/audit agreement in absorbed dose determination was within 2.2%. The median of the radiation field uniformity measurements was 2.7% and the host/audit agreement in field size was within 1 mm. Test tolerances and frequencies were within the national recommendations for kV units.
Conclusions: The dosimetric characterisation of the Papillon 50 was validated by the audit measurements for all participating centres, thus providing reassurance that the implementation had been performed within the standards stated in previously published audit work and recommendations for kV and electronic brachytherapy units. However, optimised and standardised quality assurance testing could be achieved by reducing some methodological differences observed.

1. Introduction

Regular dosimetric intercomparison has been undertaken in the UK for the past 30 years [1]. During this time audit groups in the UK have been developing and improving audit programmes with the aim of reducing the practice variability between radiotherapy departments [1,2] and maintaining quality standards across the country. An independent audit is especially useful when implementing new techniques for which commissioning and quality assurance guidelines or recommendations are not yet in place. In 2015 the National Institute of Health and Care Excellence (NICE) issued guidance on safety and efficacy of the rectal contact brachytherapy technique from a clinical perspective [3]. However, as far as we know, there is currently no guidance on equipment quality assurance testing. Electronic brachytherapy devices represent a 15% of the kV treatment units in the UK [4]. The aim of this audit was to perform a dosimetric intercomparison of the different centres and to provide an overview of the current practice in quality assurance of the systems used for rectal contact brachytherapy in the UK in order to assist current and future users to optimise their own practices as well as to establish a methodology and tolerances for future audits.

A contact brachytherapy system was released in 2008 for the treatment of early rectal cancer. It is used for conservative treatment as an alternative to radical surgery for patients at a higher anaesthetic risk or who are willing to accept a higher recurrence risk in order to avoid a permanent colostomy [5]. Contact radiotherapy can also be used as adjuvant radiotherapy to local resection, with 50 Gy usually delivered in 3 fractions, or as a boost to external beam radiotherapy, with 90–110 Gy delivered in 3 fractions [6].

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2. Materials and methods

Four centres participated in the audit, with Papillon 50 contact brachytherapy systems (Ariane Medical Systems, Ltd, Derby, UK) commissioned between 2009 and 2014 and a workload of 1–30 patients per month. A 'single auditor' approach with on-site visits was taken as a more consistent and simplified analysis methodology was easier to achieve with centrally organised audits [7–9].

Treatment with the Papillon 50 is delivered with a hand-guided X-ray tube that produces a 50 kVp and approximately 2.7 mA beam with dose rates as high as 15 Gy/min. Electrons are accelerated towards a rhenium transmission target and photons are produced isotropically. The focus-to-surface distance (FSD) of the applicators (29, 32 and 38 mm) varies with applicator diameter (22, 25 and 30 mm, respectively) in order to achieve a collimated beam with a fixed opening of 45° [6,10,11].

The audit measurements included beam quality, radiation output, and radiation field size and uniformity. A comparison between host and audit measurements was made, with a discussion of the significance of the differences observed. The National Physical Laboratory (NPL, Teddington) provided external validation of the procedures during the visit to the first audited centre [8]. Most of the dosimetry equipment used was provided by NPL, thus direct traceability for all audit results to the national standard was ensured. In addition, constancy checks using a strontium check source were carried out on the ionisation chamber by NPL before the first visit and after the last visit of the audit. A review was carried out on the quality assurance programme documentation provided by all centres [12]; this included tolerances and frequencies of tests following their respective ISO 9000 Quality Systems. A comparison was made (Table 1) to IPEM 81 recommendations [13] and to a recent review on electronic brachytherapy [6].

2.1. Beam quality (HVL)

Peak tube potential and first half-value layer (HVL_1) are the recommended beam quality specifiers for very low energy X-ray beams, such as that produced by the Papillon 50 unit. *The IPEMB code of practice (CoP) for the determination of absorbed dose for X-rays below 300 kV generating potential* [14] recommends scatter free and narrow beam geometry for the HVL measurement. Each centre had designed their own custom-built HVL jig (see Table 1 and Fig. 1 in Supplementary material) to achieve such measurement conditions; the audit HVL jig was borrowed from centre C. A PTW type 23342 0.02 cm^3 soft X-ray thin-window secondary standard parallel plate ionisation chamber calibrated in terms of air kerma and a calibrated Scanditronix Wellhofer type Dose 1 electrometer were used. All centres used the same ionisation chamber model and all the equipment was calibrated, traceable to the national standard. Temperature and pressure were measured with a Digitron handheld thermometer type 2024T and a Greisinger electronic barometer model GTD 1100, respectively. Six 99.999% purity aluminium filters were customised for this audit and their thicknesses measured at NPL with a calibrated coordinate measuring machine; the standard deviation of the thickness measurements ranged from approximately 0.002 mmAl to 0.003 mmAl for the thinnest (0.0571 mmAl) and thickest (1.039 mmAl) filters, respectively. The audited centres used their own Al filters for their measurements. Exposures of 500 MU were performed with increasing levels of attenuation using the aluminium filters. Repeat readings were corrected for temperature and pressure and the mean value plotted against the total thickness of added aluminium. The HVL value was derived from a second-degree polynomial fit and compared to the host HVL value. The effect of host-audit HVL discrepancies on the determination of absorbed dose to water was assessed.

Table 1
Summary of QC tests, frequencies and tolerances and comparison to IPEM 81 [13] and to Eaton's review on electronic brachytherapy [6].

	Frequency							Tolerance						
	Centres				IPEM 81 [13]	Eaton [6]		Centres				IPEM 81 [13]	Eaton [6]	
	A	B	C	D				A	B	C	D			
Mechanical checks														
• Papillon unit	pre-tx[a]	pre-tx	pre-tx	pre-tx	d[a]/m[a]	pre-tx		Funct[b]	Funct	Funct	Funct	Funct	Funct	
• Patient trolley and support frame														
• Int. and ext.cameras														
Safety checks														
• Interlocks and switches	m	pre-tx/m	pre-tx/m	pre-tx/m	d/m	pre-tx		Funct	Funct	Funct	Funct	Funct	Funct	
• System calibration and applicator factors														
• Warnings and beam status indicator														
• Timer														
Dosimetric checks (ionisation chamber)														
• Radiation output D_w (constancy/absolute)	pre-tx/m	pre-tx/m	pre-tx/m	pre-tx/m	d/m	pre-tx/a		2%/3%[b]	3%/5%	2%/5%	3%/5%	5%/3%	3%/10%	
• Applicator factors[c]	n/a[a]	n/a	m	n/a	a	a		n/a	n/a	2%	n/a	3%	3%	
• HVL constancy	6 m[a]	m	m	m	m	a		2%	10%	2%	5%	10%	10%	
• Linearity	m	m	c[a]	–	m	–		0.5%–5%	3–5%	1%	–	2%	–	
Radiation field checks														
• Field size	6 m	a	m	m	m	a		0.5 mm	2 mm	1 mm	qual	2 mm	1	
• Field uniformity	6 m	a	m	m	a	a		–	qual	3%	5%	5%	10%	

[a] pre-tx = pre-treatment; d = daily; m = monthly; 6 m = 6-monthly; a = annually; c = at commissioning.
[b] Tolerances stated as per 'investigation/suspension' levels. Funct = functional. Qual = qualitative.
[c] Applicator factor measurement was not performed by centres where separate calibration factors where input into the Papillon system for the different applicator sizes.