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Original Article

Accuracy and Reproducibility of Conformal Radiotherapy using Data from a Randomised Controlled Trial of Conformal Radiotherapy in Prostate Cancer (MRC RT01, ISRCTN47772397)

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RT01 Radiographer Trial Implementation Group on behalf of all the RT01 Collaborators

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ABSTRACT:
Aims: **The MRC RT01 trial used conformal radiotherapy to the prostate, a method that reduces the volume of normal tissue treated by 40–50%. Because of the risk of geographical miss, the trial used portal imaging to examine whether treatment delivery was within the required accuracy.**
Material and methods: **In total, 843 patients were randomly assigned to receive 64 Gy in 32 fractions over 6.5 weeks or 74 Gy in 37 fractions over 7.5 weeks. Field displacements and corrections were recorded for all imaged fractions. Displacement trends and their association with time, disease and treatment set-up characteristics were examined using univariate and multivariate analyses. A Radiographer Trial Implementation Group (RTIG) was set up to inform the quality assurance process and to promote the development of best practice.**
Results: **Treatment isocentre positioning was within 5 mm in every direction on 6238 (83%) of the 7535 fractions imaged. In total, 532 (81%) of 695 included patients had at least one $\geq$ 3mm displacement and 415 (63%) had at least one $\geq$ 5mm displacement. Univariate, multivariate and stepwise models of $\geq$ 5mm displacements showed an increased likelihood of displacement in weeks 1 and 2 with low melting point alloy (LMPA) blocks compared with multileaf collimators, film verification compared with electronic portal imaging (EPI) and increased number of fractions imaged. Except for LMPA, this was also seen for $\geq$ 5mm displacements in weeks 3–6.**
Conclusions: **Accurate conformal treatment was delivered. The use of EPI was associated with increased reported accuracy. The RTIG was a crucial part of the quality assurance process. Stanley, S. *et al*. (2008). *Clinical Oncology* 20, 582–590**

Key words: Conformal radiotherapy, controlled trial, portal imaging, prostate cancer, reproducibility

Introduction

Conformal radiotherapy is now a standard treatment for localised carcinoma of the prostate [1]. The MRC RT01 trial investigated the efficacy and safety of delivering dose-escalated conformal field radiotherapy for prostate cancer [2–4]. Between January 1998 and December 2001, 843 patients at 19 radiotherapy centres (17 in the UK) were randomised to receive either the standard dose (64 Gy/32 fractions) or an escalated dose (74 Gy/37 fractions). This was given as 64 Gy to the prostate and seminal vesicles (phase I) according to risk group, with or without a 10 Gy boost to the prostate only (phase II). Compared with conventional radiotherapy, conformal radiotherapy reduces the volume of normal tissue treated by 40–50% [5]. However, with this comes the risk of geographical miss due to set-up uncertainties. Therefore, regular portal imaging and image analysis was carried out to ensure that treatment delivery was within the margin of tolerance. Displacements were identified and corrections confirmed according to the protocol.

The trial quality assurance group initiated a dosimetric and geometric quality assurance review process [6]. Completion of a quality assurance questionnaire was

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a prerequisite to participation. The validity of the questionnaire responses was confirmed by visits to all UK centres during the trial where under experimental conditions using a phantom a low and acceptable variation in dosimetric and geometric uncertainty was indicated [7]. The quality assurance processes showed that all centres could deliver and verify conformal radiotherapy to the standard required to participate in the trial.

A Radiographer Trial Implementation Group (RTIG) involving radiographers from all UK participating centres was established to co-ordinate clinical aspects of the trial quality assurance process. RTIG roles included the implementation of radiographer-led portal imaging analysis, ensuring that data on treatment accuracy were collected according to protocol, monitoring technique accuracy in treatment delivery and developing and sharing best practice methods for the radiotherapy process. Displacement and correction data were collected on a radiographers' log case report form for each patient [2,8]. This paper uses the displacement and correction data submitted by the participating centres to assess the variability in the patient set-up and to comment on the accuracy of conformal radiotherapy treatments delivered during only phase I of trial radiotherapy, which was common to all trial patients.

Materials and Methods

Of 831 patients who started radiotherapy, 824 had radiographer logs returned. However, one participating centre used online imaging to verify and correct before each fraction and so no displacement data were submitted. Therefore, patients from this centre were excluded from these analyses and displacement and correction data for 695 patients were analysed.

Treatment Technique

The trial protocol allowed for three- or four-field techniques using either multileaf collimators (MLCs) or low melting point alloy (LMPA) shaped blocks (Table 1). All fields were to be treated daily on a linear accelerator of ≥ 5 MV. All patients were treated supine with locally standard immobilisation.

Computed Tomography Planning and Safety Margins

Gross tumour volume and clinical target volume were to be defined on computed tomography scans taken at 5 mm intervals from the bottom of the sacro-iliac joints to the penile urethra (1 cm below ischial tuberosities). The clinical target volume was defined as gross tumour volume + 0.5 cm and planning target volume with a three-dimensional safety margin around the clinical target volume of 0.5—1.0 cm. Each participating centre could specify their own planning target volume margin within this range to account for local set-up uncertainties. No oral, rectal or intravenous contrast agents were allowed.

Table 1 — Methods used for treatment and verification by centre

Centre*	Number of fields	Beam modification	Image type	Analysis method
2	Four-field	MLC	EPI	Software
3	Both	Both	Both	Software
4	Four-field	MLC	EPI	Software
7	Three-field	MLC	EPI	Software
8	Four-field	MLC	EPI	Software
9	Three-field	MLC	Film	Manual
10	Three-field	MLC	EPI	Software
11	Three-field	Both	EPI	Software
15	Three-field	LMPA	Film	Manual
16	Four-field	MLC	Film	Manual
17	Three-field	MLC	EPI	Software
18	Four-field	LMPA	EPI	Software
19	Three-field	MLC	EPI	Manual
20	Four-field	LMPA	Film	Manual
22	Three-field	LMPA	Film	Manual
23	Three-field	MLC	EPI	Software
25	Three-field	Both	Film	Manual
30	Four-field	MLC	Both	Software

MLC, multileaf collimator; LMPA, low melting point alloy; EPI, electronic portal imaging. *Sites have been coded. The same codes are used in Tables 1 and 2.

Verification Protocol, Radiographers' Log Displacement and Correction Data

Although in 1998 electronic portal imaging (EPI) was a recent innovation, used in relatively few UK centres, it is now an established method for determining set-up accuracy [9—13]. For the RT01 trial, an image-based verification protocol was devised to measure set-up displacements and corrections at regular intervals throughout the course of treatment. The radiographers' log used in a previous single-centre pilot study [14] was adapted to record displacement and correction data.

The trial imaging protocol defined a field placement tolerance of 3 mm in any field axis. Positioning errors ≥ 5 mm were considered unacceptable and were required to have a correction applied before the subsequent fraction being delivered. Images taken, measurements and corrections made and accuracy on the fraction after correction were recorded on the radiographers' log for each fraction imaged. Displacements were recorded for lateral, longitudinal and vertical directions from anterior/posterior and lateral/oblique views. Rotational errors were not recorded as not all centres were capable of accurately quantifying this type of error.

The trial imaging protocol also defined image frequency and megavoltage images were acquired on at least two consecutive fractions during the first week of treatment and once weekly thereafter, with repeat images after any corrections to verify the change. The timing of the image acquisition (before, during or after treatment delivery) was not defined in the protocol. All megavoltage images were compared with either a simulator film or a digitally reconstructed radiograph to determine displacements. The method of image registration used was the choice of