REPORTS OF PRACTICAL ONCOLOGY AND RADIOTHERAPY 20 (2015) 273–277

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: http://www.elsevier.com/locate/rpor

Original research article

Volumetric modulated arc therapy in prostate cancer patients with metallic hip prostheses in a UK centre

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ARTICLE INFO

Article history:
Received 3 November 2014
Received in revised form
16 February 2015
Accepted 22 March 2015

Keywords:
Arc
Hip
Prosthesis
Prostate
Radiotherapy
VMAT

ABSTRACT

Aim: This study aimed to investigate whether IMRT using VMAT is a viable and safe solution in dose escalated RT in these patients.

Background: An increasing number of prostate cancer patients are elderly and have hip prostheses. These implants pose challenges in radiotherapy treatment planning. Although intensity modulated radiotherapy (IMRT) is commonly used, there is a lack of clinical studies documenting its efficacy and toxicities in this subgroup of patients.

Materials and methods: The data from 23 patients with hip prostheses and non-metastatic prostate cancer treated with VMAT (volumetric modulated arc therapy) between 2009 and 2011, were retrospectively analyzed. Baseline characteristics, treatment details and outcome data were collected on all patients. The median follow up was 40.9 months. MRI-CT image fusion was performed and the treatment plans were created using RapidArc™ (RA) techniques utilizing 1 or 2 arcs and 10 MV photon beams.

Results: 96% of patients were treated with a dose of 72 Gy/32 fractions over 44 days. 21/23 plans met the PTV targets. The mean homogeneity index was 1.07. 20/23 plans met all OAR constraints (rectum, bladder). Two plans deviated from rectal constraints, four from bladder constraints; all were classed as minor deviations. One patient experienced late grade 3 genitourinary toxicity. Three other patients experienced late grade 2 or lower gastrointestinal toxicity. One patient had biochemical failure and one had a non-prostate cancer related death.

Conclusions: VMAT provides an elegant solution to deliver dose escalated RT in patients with unilateral and bilateral hip replacements with minimal acute and late toxicities.

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http://dx.doi.org/10.1016/j.rpor.2015.03.006
1507-1367/

1. Background

As the population ages, the number of patients presenting for radiotherapy (RT) with hip prostheses is expected to increase. According to the National Joint Registry, 86,488 hip replacements were done in 2012, a 7% increase from 2011.[1] The incidence of prostate cancer increases markedly from age 50 onwards. Hip replacement surgery is becoming common in these patients who may also have osteoarthritis of the hip. External beam RT is an established treatment option for organ confined prostate cancer, together with radical prostatectomy and active surveillance.[2]

However, treatment planning for patients with metallic prosthesis composed of high Z materials posed challenges. Dose attenuation through a hip prosthesis during pelvic irradiation can be significant, with dose losses having been reported to range between 10% and 64%. This results in inhomogeneous dose distribution in the target volume as well as at the tissue–metal interfaces.[3,4] The prosthesis causes streaking and blurring artefacts in the computed tomography (CT) dataset which prevents accurate contour delineation and alters the image density values required for dose calculation. Moreover, commercial treatment planning systems may not accurately predict doses at these tissue-metallic interfaces and may result in significant dose calculation uncertainties.[5,6]

The Task Group 63 report outlined treatment-planning strategies to overcome these challenges. A commonly used technique is the use of beam portals that avoid the prosthesis in the beam's eye view (BEV).[5] We had previously investigated the feasibility using intensity modulated radiotherapy (IMRT) in patients with hip prosthesis in our institution.[7] Inversely planned IMRT was able to deliver beams that avoided the prosthesis, which generated plans with highly conformal target volumes that spared the bladder and rectum better than corresponding 3D-conformal plans. Other researchers have investigated the use of IMRT in metallic implants as well.[8] Over the last 5 years, the use of volumetric modulated arc therapy (VMAT) systems has gained traction in the field of prostate cancer RT. VMAT system is a rotational IMRT, which allows the simultaneous variation of gantry rotation speed, dose rate, and multi leaf collimator field aperture. It is able to achieve IMRT quality dose distributions with reduction of treatment delivery times and decrement of the number of monitor units.[9] There were dosimetric studies done which demonstrated that arc radiotherapy can be effectively used in this patient group, achieving dose homogeneity despite strict constraints.[10]

2. Aim

Since 2009, we have been treating prostate cancer patients with metallic hips with RapidArc™ (Varian's solution of VMAT) and the aim of this study is to report the radiation technique and clinical data from our experience in treatment of this subgroup. To our best knowledge, this is the only series reporting both dosimetric and clinical outcomes in using VMAT system to deliver RT in patients with metallic hips.

3. Materials and methods

3.1. *Clinical evaluation*

According to literature, a follow up of 3 years is sufficient for the majority of later rectal morbidity to manifest itself.[11] We retrospectively analyzed the clinical records and RT plans of prostate cancer patients with hip replacement treated at our centre from 01/2009 to 05/2011 ($n = 23$), which resulted in a minimum follow up time of 33 months.

Patients had histologically confirmed, T1 to T3 prostate cancer adenocarcinoma evaluated by history, examination, serum prostate specific antigen (PSA) and magnetic resonance imaging (MRI) of the pelvis prior to treatment. All were treated with radical intent. Androgen deprivation therapy (ADT) consisting of LHRH analogue administration 3 months prior to RT initiation was primarily offered to patients with adverse risk features (PSA > 10, cT3, and/or Gleason ≥7). The D'Amico risk classification was used to define risk groups.

3.2. *CT simulation and contouring*

Patients were given enemas and followed a drinking protocol. CT scanning was performed with the patient in the supine position with full bladder, immobilized using ankle stocks and knee support. CT images were acquired with 3 mm spacing using a Philips Brilliance wide bore CT scanner. Additionally, an MRI scan optimized for RT planning was performed using a Philips Intera 1.5 Tesla scanner.[12] The MRI scan was fused with the planning CT in order to assist in contouring the prostate, seminal vesicles (SV), rectum, bladder and prostheses on axial slices of the CT. The high dose clinical target volume (CTV) was defined as: i) Prostate only for the low risk group ii) Prostate and base of the SV for intermediate and high risk groups. CTV was expanded 5 mm isometrically to form the planning target volume (PTV). The high dose PTV was prescribed 72 Gy/32# or 74 Gy/37#. Additional dose levels 64 Gy/32 and 50 Gy/32# were prescribed for treatment to the whole SV and pelvic lymph nodes, respectively, at physician's decision. Organs at risk (OARs) evaluated in this study were the bladder (from base to dome), rectum (from anus to recto-sigmoid flexure) and small bowels (for pelvic treatment only).

3.3. *Radiotherapy planning and optimization*

Plans were created with the Varian Eclipse TPS, version 8.9 (Varian Medical Systems, Palo Alto, CA). Either single or double arc plans were created depending on the difficulty of the individual case. For single arc plans, a clockwise arc from 180.1° to 179.9° with collimator rotation 45° was used, and for double arc plans, the second arc was a counterclockwise arc with a complement collimator angle of 315°. A beam energy of 10 MV was used for all arcs. The BEV graphics in the TPS were used to determine the arc avoidance sectors that would prevent the radiation beams from entering through the left and right prostheses. The isocentre was placed in the centre of the PTV. All plans were inversely optimized using the Varian Eclipse Progressive Resolution Optimizer (version 8.9.08) with