Megavoltage CT/MRI-Guided Radiotherapy with Endorectal Balloon Support for Prostate Cancer Patient with Bilateral Hip Prostheses

Yukihiro Hama*, Etsuko Tate
Department of Radiation Oncology, Tokyo-Edogawa Cancer Centre, Edogawa Hospital, Tokyo, Japan

*Corresponding author:
Yukihiro Hama
Department of Radiation Oncology,
Tokyo-Edogawa Cancer Centre,
Edogawa Hospital. Tokyo. Japan
yjhama2005@yahoo.co.jp

ABSTRACT

Introduction: Kilovoltage CT-guided radiotherapy for prostate cancer patients with bilateral hip prostheses can be challenging due to metal artifacts.

Case Presentation: To compensate for reduced tissue contrast and suppress metal artifacts, a 76-year-old NCCN very high-risk prostate cancer patient underwent megavoltage CT/MRI fusion image-guided radiotherapy with an endorectal balloon. The post-treatment course was uneventful. There were no recurrences or serious side effects 11 years after radiotherapy.

Conclusions: Megavoltage CT/MRI-guided radiotherapy with endorectal balloon support may be a viable alternative for a prostate cancer patient with bilateral hip prostheses.

INTRODUCTION

Image-guided intensity-modulated radiation therapy (IMRT) is a valuable treatment option for prostate cancer. However, when it comes to patients with bilateral hip prostheses, there are considerations related to metal artifacts on CT imaging that can impact treatment planning. Photon-based radical prostate radiotherapy approaches can avoid the effects of dose attenuation due to prostheses by using bimodality imaging for target and organ at risk (OAR) definition, but data loss due to metal artifacts in CT images is unavoidable [1,2].

Megavoltage CT (MVCT) is an alternative option for managing metal artifacts [3]. While MVCT excels in metal artifact reduction, it has limitations in tissue contrast. The higher energy levels used in MVCT result in lower soft tissue contrast compared to kilovoltage CT (KVCT). This reduced tissue contrast can make it difficult to visualize tumors and OARs. To compensate for the drawbacks of MVCT, MVCT-guided IMRT for prostate cancer has been performed using MRI to delineate the prostate, seminal vesicle, and surrounding tissues, and an endorectal balloon to visualize the boundary between the rectum and the prostate. This paper presents MVCT-guided IMRT with an endorectal balloon in a patient with localized prostate cancer with bilateral hip prostheses and reports long-term follow-up results over 11 years.

CASE PRESENTATION

A 76-year-old man was shown to have a prostate-specific antigen (PSA) level of 49.0 ng/mL in a routine evaluation. His physical exam was normal and the digital rectal examination revealed a slightly enlarged prostate. Prostatic biopsy revealed a Gleason score of 9 (5 + 4) adenocarcinoma. His medical history was unremarkable except for bilateral hip replacement surgery for osteoarthritis. Transverse T2-weighted MRI using a 3.0T MRI scanner (Achieva 3.0T, Philips, Amsterdam, Netherlands) showed extracapsular extension and seminal vesicle invasion (Figure 1), but whole-body CT and bone scan with 99m-Tc-labeled methylene diprophosphonate showed no lymph node or bone metastasis or metastasis to other organs.

He was diagnosed with NCCN very high-risk prostate cancer and underwent hormonal therapy with leuprolide and bicalutamide. Eight months after the initiation of hormonal therapy, the PSA level had significantly decreased to less than 0.2 ng/mL, and concurrent IMRT was performed.
Figure 1. Transverse T2-weighted turbo spin echo image shows the intermediate signal intensity mass with seminal vesicle invasion (large arrow). Metal artifacts of the bilateral hip joints are evident (small arrows) using a 3.0T MRI scanner (Achieva 3.0T, Philips, Amsterdam, Netherlands).

Figure 2. Kilovoltage CT scan for radiation treatment planning. (A) At the level of the hip joints. Pelvic organs such as the bladder and seminal vesicles are obscured by metal artifacts (arrow); (B) At the level of the prostate. The prostate is obscured by metal artifacts (arrow).

Figure 3. Megavoltage CT scan for radiation treatment planning. (A) At the level of the hip joints. Metal artifacts in the bilateral hip joints were significantly reduced. It was possible to distinguish between gas and prostate, but it became difficult to distinguish between stool (arrow) and prostate without gas; (B) At the level of the prostate. The prostate and the border between the prostate and the rectum are clearly visible (arrow).

Figure 4. Transverse T2-weighted fast spin echo image shows regression of the mass and atrophy of the seminal vesicles. Metal artifacts of the bilateral hip joints (arrow) were reduced using a 1.5T MRI scanner (Signa HDxt 1.5T, GE, Boston, Massachusetts, USA).
We initially attempted to perform radiation treatment planning (RTP) using KVCT, but due to significant metal artifacts in the bilateral hip joints (Figure 2A and 2B), it was not possible to perform RTP using KVCT alone. To reduce metal artifacts, RTP was performed with MVCT using a helical tomotherapy treatment system (TomoTherapy, ACCURAY, Madison, WI, USA). Metal artifacts in the bilateral hip joints were significantly reduced on MVCT (Figures 3A and 3B), but tissue contrast in the prostate and surrounding normal tissue was reduced, making identification difficult except for gas in the rectum.

Seminal vesicles could not be identified even on thin-section (2 mm) MVCT. To compensate for the low tissue contrast of MVCT and to reduce the metal artifact of 3.0T MRI, MRI was performed on the same day as MVCT using a 1.5T MRI unit (Signa HDxt 1.5T, GE HealthCare, Chicago, IL, USA) (Figure 4).

The rectum was fixed with an endorectal balloon (RadiaDyne, LLC, Houston, TX, USA) and air was injected into the balloon to visualize the border between the rectum and the prostate. The MRI and MVCT fusion images were used to contour the clinical target volume (CTV). The CTV was defined as the prostate along with the proximal half of the seminal vesicles. Lateral 5 mm, superior 5 mm, inferior 5 mm, anterior 5 mm, and posterior 2 mm were added to the CTV to create the planning target volume (PTV). The dose covering 95% of the PTV (D95%) was 76 Gy at 2 Gy per fraction in 38 fractions (Figure 5).

Daily positioning and target localization were performed using endorectal balloons and daily MVCT scans. Tomotherapy IMRT was delivered as planned and completed without any serious adverse events. The patient reported grade 1 dysuria, urinary frequency, and hesitancy during the course of IMRT, which resolved without treatment one month after IMRT. Hormonal therapy was continued during IMRT and for 2 years after IMRT. The patient was followed up every 6 months after IMRT with physical exams and blood tests including PSA levels, and prostate MRIs were taken every year. The six-month follow-up continued without significant impact or problems. Eleven years after IMRT, there was no recurrence of prostate cancer (PSA < 0.2 ng/mL) and no late adverse events.

**DISCUSSION**

Due to metal artifacts in KVCT images caused by bilateral hip prostheses, accurate delineation of CTVs and OARs can be challenging, and the determination of prosthesis structure and density for dose calculation is difficult [1-4]. Traditional dose calculation algorithms may not correctly model beam attenuation by high-density prostheses. Using hybrid imaging approaches that combine KVCT and MVCT and generating RTPs based on hybrid KVCT/MVCT images or MVCT images alone, using the same dose prescription and planning parameters, is one of the practical solutions [5]. RTP using MVCT/MRI fusion imaging and MVCT-guided radiotherapy with endorectal balloons may be useful when seminal vesicle invasion is present and the boundary between the rectum and prostate is unclear. To our knowledge, this is the first case of such an attempt and the longest follow-up of a prostate cancer patient with bilateral hip prostheses.

This case report has several strengths. First, by changing the magnetic field strength of the MRI to 1.5T instead of 3.0T, image distortion in MRI has been reduced (Figure 1, Figure 4). The signal-to-noise ratio (SNR) of 3.0T MRI is generally higher than that of 1.5T. The higher magnetic field strength at 3.0T results in improved SNR, which can lead to better image quality and increased sensitivity for detecting subtle anatomical details or pathological changes. Since metal artifacts are greater at 3.0T than at 1.5T, RTP using 1.5T MRI seems feasible and acceptable if adequate SNR can be ensured. Second, RTPs for prostate cancer patients with bilateral hip prostheses have been studied and proposed [1-5], but there are no reports on the long-term follow-up results of such a patient treated using MVCT/MRI fusion imaging with an endorectal balloon. This case has been followed for 11 years, making it not only the first report of MVCT/MRI fusion imaging but also the longest follow-up.

This case report has several limitations. First, state-of-the-art KVCT, photon-counting CT, has not been tested or compared with MVCT. Photon-counting CT holds great potential for improving both SNR and metal artifact reduction, but its adoption depends on...
technological advancements and clinical validation [6]. Second, because a single case report cannot be generalized to other cases, conclusions are difficult to draw at this time. Long-term follow-up of more similar cases would confirm the feasibility and efficacy of MVCT/MRI fusion image-guided IMRT.

CONCLUSIONS

A single case report cannot be generalized to others without further scientific verification; however, MVCT/MRI fusion image-guided IMRT for a prostate cancer patient with bilateral hip prostheses with endorectal balloon support may be a feasible and effective option.

DECLARATIONS

Ethics approval and consent to participate
All procedures were in accordance with the ethical standards of the National Research Committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Written informed consent was obtained from the patient for the use of clinical data in research. Since this was a retrospective case report and the treatment protocol complied with the treatment guidelines, institutional review board approval was waived.

Competing interest:
The authors declare no competing interest in this study.

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