

# Image-Guided RapidArc Treatment of the Prostate Gland and Pelvic Lymph Nodes

James L. McGee, MD, SM, FACRO

OSF Saint Francis Medical Center, Peoria, Illinois

## INTRODUCTION

Prostate cancer is the second leading cause of cancer death in American men. According to the American Cancer Society, one man in six will be diagnosed with prostate cancer during his lifetime, and one in thirty-six will die from it.<sup>1</sup> While most prostate cancers grow slowly and may not require treatment, some progress quickly and cause death within months or a few years. The decision to treat prostate cancer aggressively with radiation or other treatment options depends on an assessment of the patient's risk for local disease progression and the development of distant metastases.

An individual's risk is estimated based on his PSA level, tumor stage, and combined Gleason score. Patients at low risk are those with a PSA level less than 10, a tumor stage of T2a (a small, palpable tumor confined to the gland) or lower, and a Gleason score of 6 or less. They are predicted to have an 80 percent or greater chance of long-term control. A wait-and-see approach may be appropriate for them. Patients at high risk are those with a PSA level higher than 20, a tumor stage of T3 (local extension outside of the gland) or higher, and a Gleason score of 8 or higher. Historically, they have a 50 percent chance of long-term control and are candidates for aggressive treatment, which may include external beam radiation. Those in between are in an intermediate-risk group.<sup>2</sup>

With technology advances in external beam radiation treatment, such as image-guided radiation therapy (IGRT), intensity-modulated radiation therapy (IMRT), and volumetric modulated arc therapy (VMAT), it is possible to deliver higher doses of radiation to the prostate while sparing the bladder, rectum, and other normal tissues.<sup>3</sup> At OSF Saint Francis Medical Center, volumetric modulated arc therapy, using Varian RapidArc<sup>®</sup> radiotherapy technology, has been used to treat prostate cancer since September 2008. RapidArc treatment delivers high radiation doses with good target homogeneity, improved sparing of normal tissues, and significantly reduced treatment times.<sup>4</sup>

In this study, we discuss the large-field treatment of a prostate cancer patient with image-guided RapidArc technology. This treatment could be used for intermediate or high-risk prostate cancer patients.

## CASE REPORT

A 54-year-old man diagnosed with stage IIb prostate cancer was seen for radiation oncology consultation. The patient's primary physician, following the screening recommendations of the American Urologic Association for men over 50, ordered a PSA blood test. At 1.5, the patient's PSA value was within normal range. However, during the digital rectal examination, the physician detected a suspicious lump on the left prostate gland and referred the patient to a urologist for further evaluation, and the findings were confirmed. A biopsy was performed. Six of 12 biopsy sites from the left prostate were positive for cancer, while all biopsy samples from the right were normal. Eighty percent of the left prostate tissue was determined to be malignant. The patient's biopsy met the criteria for a Gleason score of 7—primary 4 plus secondary 3. A 1.5 Tesla MRI scan of the pelvis and prostate, performed with an endorectal coil to enhance the signal in and around the prostate, revealed the prostate to be 3.1 x 4.6 x 3.6 centimeters. In addition, a T2 hypointense 15 by 8 mm nodule was seen in the left peripheral zone extending from the prostate base to mid-gland. (See figures 1 and 2.) The patient's disease was clinical stage T2b N0 M0, pathologic stage T2b NX MX.<sup>5</sup>

## Treatment

Because of the characteristics of his disease, it was felt that this patient needed aggressive treatment with androgen deprivation therapy and either (1) external beam radiation or (2) a combination of high-dose-rate (HDR) interstitial brachytherapy and external beam radiation.

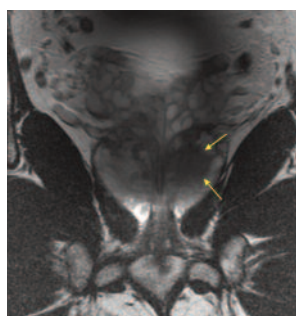
For three months before radiation therapy, the patient took Casodex (bicalutamide) tablets and received Lupron-Depot (leuprolide) injections. Patient tolerance of the hormone therapy was favorable. The patient elected to be treated with a full course of external beam radiation therapy with Varian RapidArc technology on a Trilogy<sup>®</sup> system.

Using the Memorial Sloan-Kettering prediction tools for prostate cancer (<http://www.mskcc.org>), the patient's pretreatment chance of having organ-confined disease was 60 percent, based on his PSA value, clinical exam, and biopsy results. The estimated risk of extracapsular extension was 32 percent and the risk of lymph node involvement was 3 percent. Thus, local control of the disease was very important to the patient's ultimate outcome. Since the total dose of radiation to the prostate itself correlates with the chance of local control,<sup>6</sup> a dose of 86.4 Gy in 48 fractions delivered with intensity modulation to protect the rectum, small bowel, and bladder was recommended. The seminal vesicles were to be treated to 81 Gy, and it was decided with the patient to electively irradiate the pelvic lymph nodes.

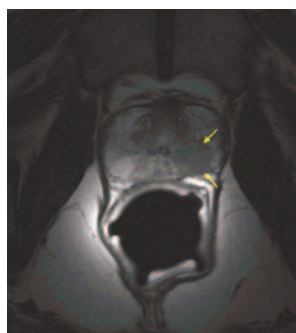
In September 2009, carbon fiber fiducial markers were implanted in the prostate via a transperineal approach under anesthesia, guided by axial and sagittal transrectal ultrasound (TRUS) images. The fiducial markers help in contouring of the prostate, particularly if one is placed just at the prostatic apex to define the lower border of the prostate. A second marker is placed near the base, and a third is positioned in the mid-gland in a staggered configuration. These markers can easily be imaged and aligned at the time of treatment with the 2D-2D image-matching capabilities of the Varian On-Board Imager® kV imaging system. Carbon fiber markers are used because they cast fewer artifacts on CT simulation images. CT simulation is carried out one week after the fiducial markers are placed in order to assure that they do not migrate after planning images are obtained.

We planned the treatment using the Varian Eclipse™ treatment planning system. RapidArc optimizations were performed in Eclipse 8.6. The treatment plan was designed based on the dose constraints for the bladder, rectum, and other normal tissues established by the Memorial Sloan-Kettering Cancer Center.<sup>7,8</sup>

The plan was developed to treat the prostate to 86.4 Gy, the seminal vesicles to 81 Gy, and the pelvic lymph nodes to 45 Gy, all at 1.8 Gy per fraction. (See figures 3, 4, and 5 for treatment plan images. See table 1 for the dose parameters.) RapidArc technology provided the dose-shaping characteristics needed to treat the lymph nodes, seminal vesicles, and prostate to the desired doses while still meeting the normal tissue dose constraints. Compared to IMRT, RapidArc reduced the time that this patient must lie on table from approximately 20 minutes to 7 minutes or less, including the time for 2D-2D or 3D-3D image matching with the cone-beam CT. Reducing the daily treatment time was an important consideration for this patient. He previously had a spinal laminectomy that made it uncomfortable for him to lie on the table for more than a few minutes at a time.



**Figure 1.** T2 weighted coronal MRI of prostate with endorectal coil demonstrating dominant hypointense tumor nodule in left lobe (arrows) extending from base to apex.



**Figure 2.** T2 weighted axial MRI of prostate with endorectal coil demonstrating dominant hypointense tumor nodule in left lobe (arrows) extending from base to apex.

**Table 1: Definitions and doses**

All definitions and doses are from *A Practical Guide to Intensity-Modulated Radiation Therapy*.<sup>7</sup>

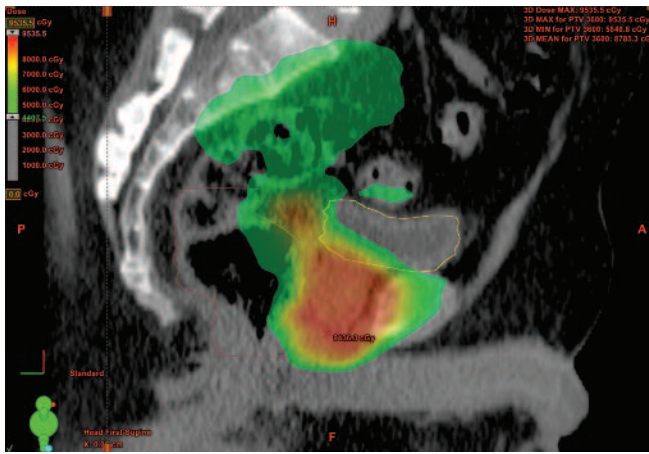
PTV	(Prostate + SV) + 0.6 cm margin
PTVE <sup>*</sup>	PTV = 0.25 cm/0 mm post.
Rx <sup>†</sup>	8640
PTV V95	8208 (90% Rx)
PTV max. dose	9590 (111% Rx)
Rectal wall V30 <sup>‡</sup> §	7560
Rectal wall V53	4700
Rectal wall V5	7700
Bladder wall V53 <sup>§</sup>	4700
Bladder wall V5	7950
Fem. hd. max.	6800
Small bowel V2	4500
Sigmoid max.	6000
Sigmoid V10	5000

\* PTVE = PTV expanded to account for dose contraction at field edge.

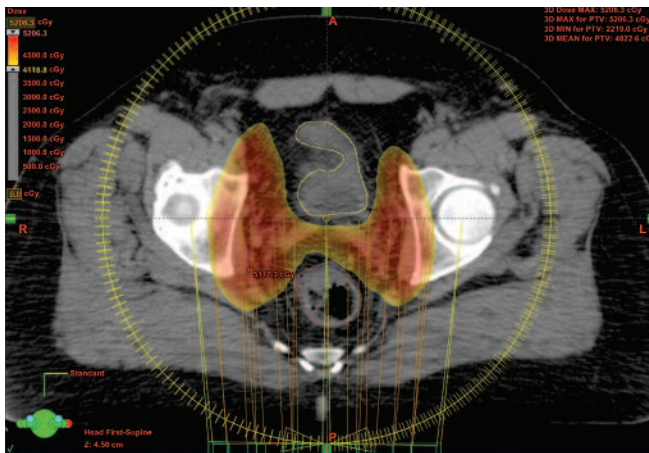
† Measurement in centigray (cGy).

‡ Anatomy Vxx = dd means: Not more than xx percent of the volume of the structure.

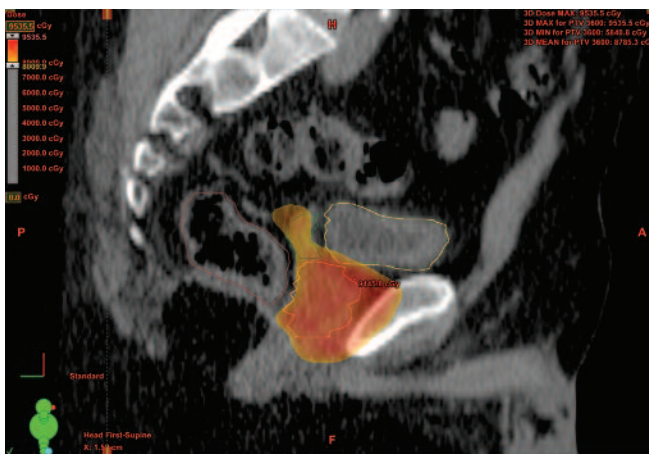
§ Rectal and bladder walls are defined as outer wall minus inner wall over the length of the PTV plus 1 cm above and 1 cm below the PTV.



**Figure 3.** Eclipse treatment plan of two-arc RapidArc plan with color wash demonstration in sagittal view of dose over 44 Gy. Prescribed dose was 45 Gy to pelvic nodes, 81 Gy to seminal vesicles, 86.4 Gy to prostate.



**Figure 4.** Eclipse treatment plan of two-arc RapidArc plan with color wash demonstration in axial view of dose over 41 Gy. Prescribed dose to pelvic nodes was 45 Gy.



**Figure 5.** Eclipse treatment plan of two-arc RapidArc plan with color wash demonstration in sagittal view of dose over 80 Gy. Prescribed dose was 81 Gy to seminal vesicles, 86.4 Gy to prostate.

## Image guidance

For this and all prostate cases, we use the On-Board Imager for daily patient setup and target localization. Daily we take radiographs to register the fiducial markers in two dimensions with the reference images. On the first five days of treatment, we acquire an on-board cone-beam CT scan and compare it with the CT images from the treatment plan to verify the position of the bladder and rectum in three dimensions. If the initial week of images does not show any marked bladder, rectal, or small bowel changes over that time, we continue with daily 2D-2D orthogonal set-up matching and do a check cone-beam CT once per week. If a patient does not have fiducial markers placed, we proceed with daily cone-beam CT alignments. Fiducial markers are optional, and excellent daily localizations with cone-beam CT without daily fiducials are very acceptable.

Three-dimensional imaging shows if the rectum is bulging into the planned treatment volume. Verifying the shape and position of the bowel is especially important when treating larger fields that include pelvic lymph nodes, as in this case. During the course of treatment, the rectum can become irritated and fill less as a result. Weekly on-board CT scans reveal significant changes in the size and location of the rectum or prostate that could cause us to replan the treatment. We find it necessary to institute medical measures for rectal volume management or to replan treatments in approximately 5 percent of prostate cases.

## Results

Treatment has been completed, and the patient tolerated the therapy quite well. No major bowel or bladder symptoms were seen, despite the high doses of radiation delivered.

## CONCLUSIONS

In image-guided radiotherapy, the use of 2D-2D image matching with implanted fiducial markers is a quick and simple means of beam alignment prior to radiation treatment. The 3D-3D image-matching process with cone-beam CT is also highly desirable because it allows us to see when gas or stool in the rectum has caused a significant volume of the rectum to shift into the high-dose volume. In some instances, particularly when the seminal vesicles are included in the treatment volume, this may happen and not affect the position of the fiducial markers. Thus, a 2D-2D alignment alone may not adequately protect the patient from the late effects of radiation. Our policy of five daily initial and subsequent weekly image matching, including cone-beam CT images, seeks to assure that our planning images are representative of

the position of the organs during treatment. Fiducial markers, particularly when placed with care by the radiation oncologist using axial and sagittal TRUS images, can be very valuable in defining the prostatic apex, which provides assurance in contouring. It is not difficult to imagine that “dose painting” may be used in the near future to escalate the dose to tumor nodules, as seen in this patient’s MRI study.

Regardless of whether one is undertaking conventional radiation therapy, dose painting, or hypofractionated stereotactic body radiotherapy, the ability to see the target with 3D CT images and make alignment adjustments is critical to success. Also critical is the ability to deliver the treatment to the whole target volume rapidly, before the target and normal tissue relationships can change, and in a manner most consistent with a good radiobiologic characteristic of the treatment. RapidArc technology is a great practical boon in the clinic because many patients can be treated on one machine with very sophisticated plans. Prostate cancer patients are typically treated in 7.5-minute time slots, including the cone-beam CT image matching. As doses per fraction for prostate and other cancers are being increased, the use of the viewable 3D images provided by the On-Board Imager and the RapidArc delivery of high doses in a time frame consistent with HDR radiobiology are very desirable for both their practicality and their elegance.

## Endnotes

1. American Cancer Society. What are the key statistics about prostate cancer? Available at: [http://www.cancer.org/docroot/CRI/content/CRI\\_2\\_4\\_1X\\_What\\_are\\_the\\_key\\_statistics\\_for\\_prostate\\_cancer\\_36.asp](http://www.cancer.org/docroot/CRI/content/CRI_2_4_1X_What_are_the_key_statistics_for_prostate_cancer_36.asp). Accessed March 5, 2010.
  2. Diblasio CJ, Kattan MW. Use of nomograms to predict the risk of disease recurrence after definitive local therapy for prostate cancer. *Urology*. 2003;62:1(suppl):9–18.
  3. Otto K. Volumetric modulated arc therapy: IMRT in a single gantry arc. *Med Phys*. 2008;35:310–317.
  4. Kjær-Kristoffersen F, et al. RapidArc volumetric modulated therapy planning for prostate cancer patients. *Acta Oncol*. 2009;48:227–232.
  5. Pretreatment endorectal MRI and magnetic resonance spectroscopy findings with prostate cancer are felt by some to be more accurate independent predictors of outcome than clinical variables. In particular, the findings of seminal vesicle invasion and extensive tumor predict a worse prognosis. Reference: Joseph T, et al. Pretreatment endorectal magnetic resonance imaging and magnetic resonance spectroscopic imaging features of prostate cancer as predictors of response to external beam radiotherapy. *Int J Radiat Oncol Biol Phys*. 2009;73:665–671.
- Furthermore, pretreatment MRI may be used in the future to assess tumor volumes within the prostate that may benefit from higher doses of radiation. Reference: van Vulpen M, et al. Difficulties and potential of correlating local recurrences in prostate cancer with the delivered local dose. *Radiother Oncol*. 2009;93:180–184.
6. Cahlon O, et al. Ultra-high dose (86.4 Gy) IMRT for localized prostate cancer: toxicity and biochemical outcomes. *Int J Radiat Oncol Biol Phys*. 2008;71:330–337.
  7. Skwarchuk M, et al. Late rectal toxicity after conformal radiotherapy of prostate cancer (I): multivariate analysis and dose-response. *Int J Radiat Oncol Biol Phys*. 2000; 47:103–113.
  8. *A Practical Guide to Intensity-Modulated Radiation Therapy*. Medical Physics Publishing; 2003.



**USA Headquarters** Varian Medical Systems, Palo Alto, CA | Tel: 650.424.5700 800.544.4636 | <http://www.varian.com>  
**Latin American Headquarters** Varian Medical Systems, Miami, FL USA | Tel: 305.929.1970  
**European Headquarters** Varian Medical Systems International AG | Zug, Switzerland | Tel: 41.41.749.8844  
**Asian Headquarters** Varian Medical Systems Pacific, Inc. | Kowloon, Hong Kong | Tel: 85.22.724.2836  
**Australian Headquarters** Varian Medical Systems Australasia Pty Ltd. | Sydney, Australia | Tel: 61.2.9485.0111