

Anatomy-based volumetric modulated arc therapy for a prostate cancer patient with a hip prosthesis

Naoaki KUNISHIMA^{1,*}, Yutaka NAOI¹ and Kiyoshi YODA²

¹Department of Radiology, Self Defense Forces Central Hospital, 1-2-24 Ikejiri Setagaya-ku, Tokyo 154-0001, Japan

²Elekta KK, 3-9-1 Shibaura, Minato-ku, Tokyo 108-0023, Japan

*Corresponding author: Tel: +81-3-3411-0151; Fax: +81-3-3411-0093; Email: kunishima17@gmail.com

(Received 27 May 2012; revised 30 September 2012; accepted 1 October 2012)

High-atomic number materials such as those used in making artificial bones or prostheses, spinal cord fixation devices and dental fillings may be located in patients undergoing radiotherapy. These devices may have a major influence on absorbed dose distributions in the body, as they cause significant beam attenuation and scattering. A report of the American Association of Physicists in Medicine described the clinical dosimetry methodology used for a patient with a hip prosthesis and recommended beam arrangements without passing through the prosthesis [1].

Volumetric modulated arc therapy (VMAT) has been increasingly used for the treatment of patients with prostate cancer because it is associated with fewer monitor units and higher patient throughput than those in step-and-shoot intensity modulated radiotherapy [2]. However, to the authors' best knowledge, no reports have been published regarding VMAT for a prostate cancer patient with a hip prosthesis. The purpose of this letter is to propose a simple anatomy-based VMAT strategy for a prostate cancer patient with a hip prosthesis, using ERGO++ (Elekta, Stockholm Sweden) [3], a treatment planning system (TPS) based on hollow-out conformation radiotherapy [4]. ERGO++ VMAT allows the delivery of a uniform dose to the prostate target, while efficiently protecting the rectum and other healthy organs. As a routine prostate VMAT planning procedure in ERGO++, either conformal or conformal avoidance fields were applied when the target was in front of the rectum, or when the rectum was in front of the target, respectively. Subsequently, VMAT optimization was performed by determining the best beam intensity variations for all the beam directions under the given dose constraints.

Our findings were as follows: (i) a clinically acceptable plan was successfully established by considering a unilateral hip prosthesis and contralateral femur in addition to the rectum when conformal avoidance fields were defined, and

(ii) a single-rotation VMAT required three separate subarcs, thereby avoiding beam angles that directly went through the prosthesis and femur.

A VMAT plan was established using ERGO++ version 1.7.4. For the patient with a prosthesis, Versys HA/TCP Fiber Metal Midcoat Stem, Multipolar Cup, and Nitride Head/Neck (Zimmer, USA) were used in place of the right femur, which had a stem thickness of 14 mm, a head size of 52 mm, and a neck size of 3.5 × 22 mm. The stem was made of a titanium alloy (90% titanium), and the head was made of a cobalt-chromium alloy. The clinical target volume (CTV) consisted of the entire prostate and partial seminal vesicles, as visualized on the CT axial images. A planning target volume (PTV) was obtained by adding a margin of 5 mm in the dorsal direction and a margin of 8 mm in the other directions to the CTV. A planning organ-at-risk volume (PRV) was obtained by adding an isotropic margin of 2 mm to the prosthesis for more complete beam shielding. A multileaf collimator (MLC) margin of 6 mm was further applied to compensate for the beam penumbra.

Figure 1 shows the beam's eye views for a single-rotation anatomy-based VMAT plan. We found that an arc of 360° needed to be divided into 3 separate subarcs at the beam angles, where the PRV or left femur was positioned right in front of the PTV. Conformal fields were applied when the PTV was in front of the PRV, rectum or left femur, whereas conformal avoidance fields were applied when the PRV, rectum or left femur was in front of the PTV. When the PRV was in front of the PTV (in subarcs 1 and 2), the PRV was fully shielded. Initially, the left femur was not shielded; therefore, two separate subarcs were used, resulting in significantly higher doses in the left femur and left-side pelvic bone. To reduce the doses in these regions, the left femur was shielded, thereby leading to a 3-subarc plan. For the best radiation shield, the

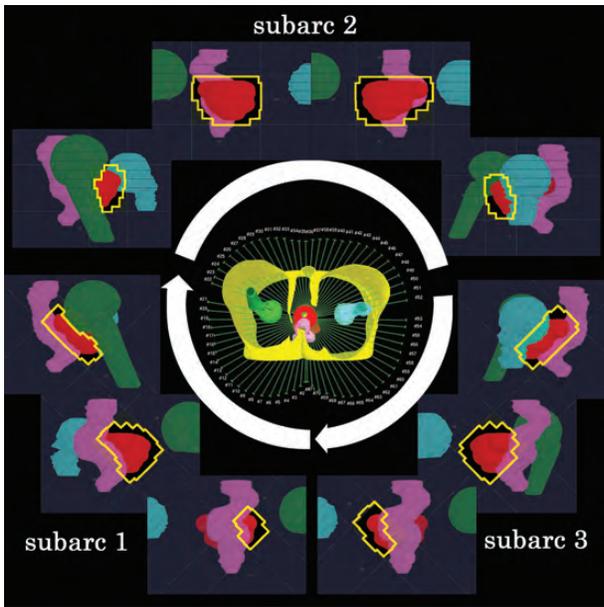


Fig. 1. Beam's eye views for the single-rotation anatomy-based VMAT plan comprising three subarcs created by an ERGO++ treatment planning system. Field shapes are depicted as yellow closed lines with MLC leaves overlaid. The colors of the organs are as follows: PTV, red; rectum, magenta; PRV (hip prosthesis with a 2-mm margin), green; and left femur, sky blue. Conformal fields were applied when the PTV was in front of the PRV, rectum or left femur, whereas conformal avoidance fields were applied when the PRV, rectum or left femur was in front of the PTV. When the PRV was in front of the PTV (in subarcs 1 and 2), the PRV was fully shielded. The collimator angle was optimized for each of the three subarcs for the best radiation shield.

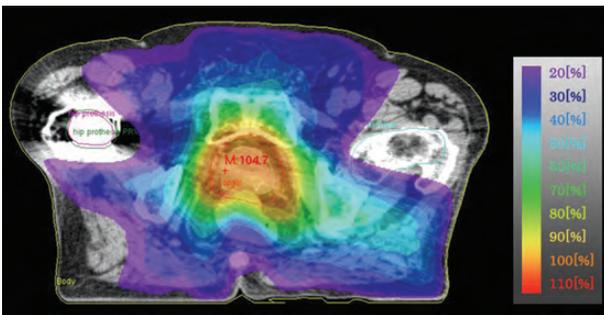


Fig. 2. Calculated dose distributions overlaid on an axial CT slice, including the isocenter. The dose inside the hip prosthesis in place of the right femur was lower than 20% of the prescribed isocenter dose.

collimator angle was manually optimized to 45° in subarcs 1 and 3, and 0° in subarc 2. Inhomogeneity correction was not used for dose calculation because of metal artifacts, and a prescription dose of 78 Gy in 39 fractions was delivered to the isocenter. To estimate the impact of ignored inhomogeneity correction, the bones were contoured and the dose distributions were recalculated with a bone relative electron

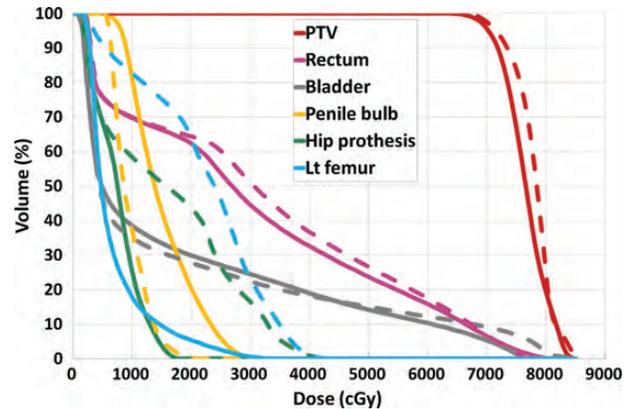


Fig. 3. Resulting dose volume histogram for the PTV, rectum, bladder, penile bulb, hip prosthesis and left femur. The solid lines indicate the DVH of the proposed 3-arc VMAT plan, whereas the dashed lines indicate that of a full-arc VMAT plan without the strong constraint for the PRV described earlier. The proposed plan highly reduced the dose in the left femur, while slightly sacrificing the PTV dose uniformity.

density of 1.1. The recalculated isocenter dose was 77.65 Gy, which was 0.5% less than that without inhomogeneity correction, indicating clinical insignificance. The monitor units in each beam direction were optimized under the given dose constraints for the PTV and organs at risk (OAR).

The resulting plan satisfied all of the dose constraints for the OAR outlined in the RTOG 0126 protocol (rectum: $V75 \leq 15\%$, $V70 \leq 25\%$, $V65 \leq 35\%$, and $V60 \leq 50\%$; bladder: $V80 \leq 15\%$, $V75 \leq 25\%$, $V70 \leq 35\%$, and $V65 \leq 50\%$; urethrobular mean dose ≤ 52.5 Gy). Meanwhile, the PTV maximum dose was 84.2 Gy, and D95 (dose covering 95% of the PTV) was 70.2 Gy. The homogeneity index was 140.3%.

Figure 2 depicts the calculated dose distributions overlaid on an axial CT slice including the isocenter. It is shown that the dose inside the hip prosthesis in place of the right femur was lower than 20% of the prescribed isocenter dose. Figure 3 shows a dose volume histogram (DVH) for the PTV, rectum, bladder, penile bulb, hip prosthesis and left femur. The solid lines depict the DVH of the proposed 3-arc VMAT plan, whereas the dashed lines indicate that of a full arc VMAT plan without the strong constraint for the PRV described earlier. The proposed plan highly reduced the dose in the left femur, while slightly sacrificing the PTV dose uniformity. The resulting VMAT sequence was exported to an Elekta linac controller (Desktop Pro 7.01, Elekta) via a record-and-verify system (Mosaik version 2.0, Elekta). The total monitor units were 377.9 MU, and the beam delivery time was 135 seconds.

In conclusion, it has been demonstrated for the first time that prostate VMAT for a patient with a unilateral hip prosthesis is possible by using the anatomy-based conformal

avoidance technique with the ERGO ++ TPS. VMAT for a patient with bilateral hip prostheses may also be considered feasible.

ACKNOWLEDGEMENTS

The data reported in this letter were presented in part at the ESTRO31 Conference of the European Society of Radiotherapy and Oncology, Barcelona, Spain, 9–13 May 2012.

REFERENCES

1. Reft C, Alecu R, Das IJ *et al.* Dosimetric considerations for patients with HIP prostheses undergoing pelvic irradiation. Report of the AAPM Radiation Therapy Committee Task Group 63. *Med Phys* 2003;**30**:1162–82.
2. Pasler M, Wirtz H, Lutterbach J. Impact of gantry rotation time on plan quality and dosimetric verification - volumetric modulated arc therapy (VMAT) vs. intensity modulated radiotherapy (IMRT). *Strahlenther Onkol* 2011;**187**:812–9.
3. Haga A, Nakagawa K, Shiraishi K *et al.* Quality assurance of volumetric modulated arc therapy using Elekta Synergy. *Acta Oncol* 2009;**48**:1193–7.
4. Takahashi S, Iida H. Experimental study on partial shielding radiation and hollow out radiation technique. Studies on rotatory conformation radiotherapy (Report 5). Studies on telecobalt therapy (Report 13). *Nippon Acta Radiol* 1961;**21**:126–31. <http://ir.library.osaka-u.ac.jp/metadb/up/LIBLSK001/JJRS-21-2-126-131.pdf> (21 October 2012, date last accessed).