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DOSIMETRIC COMPARISON OF 6 MV AND 15 MV SINGLE ARC RAPIDARC TO HELICAL TOMOTHERAPY FOR THE TREATMENT OF PANCREATIC CANCER

JING CAI, PH.D., JINBO YUE, M.D., ROBERT MCLAWHORN, PH.D., WENSHA YANG, PH.D., KRISHNI WIJESOORIYA, PH.D., NEAL E. DUNLAP, M.D., KE SHENG, PH.D., FANG-FANG YIN, PH.D., and STANLEY H. BENEDICT, PH.D.

Department of Radiation Oncology, Duke University Medical Center, Durham, NC; Department of Radiation Oncology, University of Virginia, Charlottesville, VA; and Department of Radiation Oncology, Shandong Cancer Hospital, Jinan, Shandong, China

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Abstract—We conducted a planning study to compare Varian's RapidArc (RA) and helical TomoTherapy (HT) for the treatment of pancreatic cancer. Three intensity-modulated radiotherapy (IMRT) plans were generated for 8 patients with pancreatic cancer: one using HT with 6-MV beam ($Plan_{\_HT6}$), one using single-arc RA with 6-MV beam ($Plan_{\_RA6}$), and one using single-arc RA with 15-MV beam ($Plan_{\_RA15}$). Dosimetric indices including high/low conformality index ($CI_{100\%}/CI_{50\%}$), heterogeneity index (HI), monitor units (MUs), and doses to organs at risk (OARs) were compared. The mean $CI_{100\%}$ was statistically equivalent with respect to the 2 treatment techniques, as well as beam energy (0.99, 1.01, and 1.02 for $Plan_{\_HT6}$, $Plan_{\_RA6}$, and $Plan_{\_RA156}$, respectively). The $CI_{50\%}$ and HI were improved in both RA plans over the HT plan. The RA plans significantly reduced MU (MU_{RA6} = 697, MU_{RA15} = 548) compared with HT (MU_{HT6} = 6177, p = 0.008 in both cases). The mean maximum cord dose was decreased from 29.6 Gy in $Plan_{\_HT6}$ to 21.6 Gy (p = 0.05) in $Plan_{\_RA6}$ and 21.7 Gy (p = 0.04) in $Plan_{\_RA15}$. The mean bowel dose decreased from 17.2 Gy in $Plan_{\_HT6}$ to 15.2 Gy (p = 0.03) in $Plan_{\_RA6}$ and 15.0 Gy (p = 0.03) $Plan_{\_RA15}$. The mean liver dose decreased from 8.4 Gy in $Plan_{\_HT6}$ to 6.3 Gy (p = 0.04) in $Plan_{\_RA6}$ and 6.2 Gy in $Plan_{\_RA15}$. Variations of the mean dose to the duodenum, kidneys, and stomach were statistically insignificant. RA and HT can both deliver conformal dose distributions to target volumes while limiting the dose to surrounding OARs in the treatment of pancreatic cancer. Dosimetric advantages might be gained by using RA over HT by reducing the dose to OARs and total MUs used for treatment. **© 2011 American Association of Medical Dosimetrists.**

Key Words: **RapidArc, Tomotherapy, Pancreatic cancer.**

INTRODUCTION

The outcome of locally advanced pancreatic cancer remains poor, with a median survival of 10 months.[1] The use of 3D conformal radiotherapy (3D-CRT) is limited by increased toxicity as a result of irradiation of surrounding organs such as liver, kidneys, and small bowel. Intensity-modulated radiotherapy (IMRT) has been shown to improve conformal avoidance when compared with 3D-CRT techniques.[2–4] The availability of more sophisticated IMRT techniques, such as helical TomoTherapy (HT) and the newly introduced Varian's RapidArc (RA) (Varian Medical Systems, Palo Alto, CA), triggered interest in performing a planning study of these IMRT techniques on treatment of pancreatic cancer.

HT is an arc-based approach of IMRT using a fan-beam of radiation in conjunction with a binary multileaf collimator (MLC). The gantry rotates at a constant speed while the binary MLC leaves open 51 times per rotation and close entirely between different "projections." This complex rotational method of treatment delivery may improve the dose conformity and organs at risk (OARs) sparing compared with the fixed-beam method of IMRT using a limited number of beam directions.[5–7] RA is a planning and delivery approach based on volumetric intensity-modulated arc therapy[8] and falls into the more general category of IMRT with arcs. RA uses continuous variation of the instantaneous dose rate, MLC leaf positions, and gantry rotational speed to optimize the dose distribution. Compared with the conventional multistatic-fields IMRT, RA have been shown to reduce the treatment delivery time while maintaining similar plan quality in some treatment sites such as prostate, brain, head and neck, and breast.[9–11]

Although HT has only one choice of beam energy (nominal beam energy of 6 MV), RA allows the use of multiple-beam energies (in our institution they are 6-MV or 15-MV photon beams). The use of higher energy beams might be advantageous in the treatment of target volumes centered deep in the body, such as pancreatic

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Reprint requests to: Jing Cai, Ph.D., Department of Radiation Oncology, Duke University Medical Center, Box 3295, Durham, NC 27710. E-mail: jing.cai@duke.edu

cancer. In this study, we performed a dosimetric comparison between treatment plans of 6-MV and 15-MV RA and HT for treatment of pancreatic cancers.

METHODS AND MATERIALS

A plan comparison study was performed using 8 pancreatic cancer patients (3 male, 5 female, mean age: 62.1) who had originally undergone planning and treatment using HT (TomoTherapy, Madison, WI). CT images were acquired with patients in the supine position with a custom immobilization device. Diagnostic CT or MRI images were registered with the planning CT for target delineation. The gross target volume (GTV) was identified from these images after review with the intentional and diagnostic radiologists. The planning target volume (PTV) consisted of a 1.5-cm radial expansion and a 2-cm craniocaudal expansion GTV. The mean volume for PTV was 618.9 cm^3, minimum 130.6 cm^3 and maximum 2350.0 cm^3. All patients received a prescription of 50 Gy delivered in 20 fractions (2.5 Gy/fraction). Treatment planning was performed with the aim to minimize the dose to normal liver while also sparing the kidneys. All plans were normalized such that the 95% of the PTV was covered by 100% of the prescribed dose.

Three IMRT treatment plans were generated for each patient: a HT plan with 6-MV beam ($Plan_{\_HT6}$), a single-arc RA plan with 6-MV beam ($Plan_{\_RA6}$), and a single-arc RA plan with 15-MV beam ($Plan_{\_RA15}$). All contours were generated using AcQsim software (Philips Medical System North America, Bothell, WA) and then transferred to the planning systems for treatment planning. The OAR included liver, kidneys, spinal cord, duodenum, bowel, and stomach. HT plans were generated using the Hi-Art Helical Tomotherapy inverse planning software. A collimator aperture of 2.5 cm, a pitch of 0.287, and a modulation factor of 2.5 were used. Dose calculations were performed using the fine-dose calculation grid (3 mm in craniocaudal direction and over a 256×256 matrix in axial plane from the original CT scan). A TomoTherapy treatment table was inserted during the calculation.

RA plans were generated using the Eclipse planning system (Version 8.5, Varian Medical Systems) with the Millennium-120 leaf MLC. The anisotropic analytical algorithm (AAA) dose calculation algorithm was used and the treatment table was not considered in the dose calculation. Single-arc treatment field rotating from 179–181° was used in all RA plans. A maximum dose rate of 600 MU/min dose rate was used so the dose rate varied between 0 MU/min and 600 MU/min. The collimator rotation and jaw positions were optimized by the treatment planning system.

Quantitative evaluation of plans was performed by means of standard dose-volume histogram (DVH). The degree of conformality of the plans was measured with a conformity index (CI). $CI_{100\%}$ and $CI_{50\%}$ are defined as the ratio between the patient volume receiving at least 100% and 50% of the prescribed dose and the volume of the PTV, respectively. Homogeneity index (HI) is defined as the difference between the dose to 1% volume and the dose to 99% volume, divided by the prescription dose.[12] A more homogeneous plan will score closer to zero. For the OARs, the analysis included the mean dose and the maximum dose. To appraise the difference between the techniques, the paired, two-tailed Student's *t*-test was applied. Data were considered statistically significant for $p < 0.05$.

RESULTS

Figure 1 shows the dose distributions from the HT and RA plans of a pancreatic cancer patient. Table 1 summarizes the average dosimetric indices and the comparisons between the three plans and. On average, the mean CI, $CI_{100\%}$, was statistically equivalent with respect to the 2 treatment techniques as well as beam energy. The mean $CI_{100\%}$ values were 1.01 and 1.02 for the 6-MV and 15-MV RA plans, respectively, whereas the mean $CI_{100\%}$ was 0.99 for HT. However, the low-dose spillage of $CI_{50\%}$ was improved significantly in both the 6-MV ($CI_{50\%} = 2.96$, $p = 0.01$) and 15-MV RA plans ($CI_{50\%} = 3.32$, $p = 0.01$) over the HT plan ($CI_{50\%} = 4.64$). The RA plans significantly improve the HI ($HI_{\_RA6} = 1.10$, $HI_{\_RA15} = 1.11$) compared with HT ($HI_{\_HT6} = 1.05$, $p = 0.01$). The $CI_{100\%}$, $CI_{50\%}$, and HI were insignificant between 6-MV and 15-MV RA plans. As expected, the RA plans significantly reduce the mean number of MUs ($MU_{\_RA6} = 697$, $MU_{\_RA15} = 548$) compared with HT ($MU_{\_HT6} = 6177$, $p = 0.01$). The difference in the number of MUs for the 6-MV and 15-MV RA plans was also significant ($p = 0.04$).

There is no significant difference in the maximum cord dose and mean stomach dose between the HT plan and two RA plans (6 MV and 15 MV). There are significant but small differences in the mean doses to the bowel, duodenum, kidney, and liver. Doses to these OARs are slightly decreased in the 6-MV and 15-MV RA plans than in the HT plan.

DISCUSSION

In this study we performed a dosimetric planning comparison between RA and HT for the treatment of pancreatic cancer. Our preliminary results indicated that single-arc RA plans with either 6-MV or 15-MV photon beams were able to provide comparable plan quality when compared with the HT plans while significantly reducing the number of MUs. Some comparison studies between the two techniques have actually been recently conducted, *e.g.*, Cao *et al.*[13] and Fogliata *et al.*[14] In the study by Cao *et al.*, it is concluded that in the most complex cases, HT has a dosimetric advantage over single-arc RA. However, the authors acknowledge that the differences may be in part a result of their specific implementation of IMAT optimization by use of an "arc-

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