International Journal of
Radiation Oncology
biology • physics

www.redjournal.org

Clinical Investigation: Gynecologic Cancer

Dosimetric Comparison of Combined Intensity-Modulated Radiotherapy (IMRT) and Proton Therapy Versus IMRT Alone for Pelvic and Para-Aortic Radiotherapy in Gynecologic Malignancies

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Received Nov 8, 2010, and in revised form May 18, 2011. Accepted for publication Jul 12, 2011

Summary

This manuscript presents a dosimetric comparison of intensity-modulated radiotherapy (IMRT), passive scattering proton therapy (PSPT), and intensity-modulated proton therapy (IMPT) to the para-aortic (PA) nodal region in women with locally advanced gynecologic malignancies. Two groups of treatment plans including proton radiotherapy were created: IMRT to pelvic nodes with PSPT to PA nodes (PSPT/IMRT), and IMRT to pelvic nodes with IMPT to PA nodes (IMPT/IMRT). The IMRT and proton RT plans were optimized to deliver 50.4 Gy (RBE). The small-bowel V_{20} was reduced in PSPT/IMRT

Purpose: To perform a dosimetric comparison of intensity-modulated radiotherapy (IMRT), passive scattering proton therapy (PSPT), and intensity-modulated proton therapy (IMPT) to the para-aortic (PA) nodal region in women with locally advanced gynecologic malignancies.
Methods and Materials: The CT treatment planning scans of 10 consecutive patients treated with IMRT to the pelvis and PA nodes were identified. The clinical target volume was defined by the primary tumor for patients with cervical cancer and by the vagina and paravaginal tissues for patients with endometrial cancer, in addition to the regional lymph nodes. The IMRT, PSPT, and IMPT plans were generated using the Eclipse Treatment Planning System and were analyzed for various dosimetric endpoints. Two groups of treatment plans including proton radiotherapy were created: IMRT to pelvic nodes with PSPT to PA nodes (PSPT/IMRT), and IMRT to pelvic nodes with IMPT to PA nodes (IMPT/IMRT). The IMRT and proton RT plans were optimized to deliver 50.4 Gy or Gy (relative biologic effectiveness [RBE]), respectively. Dose–volume histograms were analyzed for all of the organs at risk. The paired *t* test was used for all statistical comparison.
Results: The small-bowel V_{20}, V_{30}, V_{35}, andV_{40} were reduced in PSPT/IMRT by 11%, 18%, 27%, and 43%, respectively ($p < 0.01$). Treatment with IMPT/IMRT demonstrated a 32% decrease in the small-bowel V_{20}. Treatment with PSPT/IMRT showed statistically significant reductions in the body V_{5-20}; IMPT/IMRT showed reductions in the body V_{5-15}. The dose received by half of both kidneys was reduced by PSPT/IMRT and by IMPT/IMRT. All plans maintained excellent coverage of the planning target volume.
Conclusions: Compared with IMRT alone, PSPT/IMRT and IMPT/IMRT had a statistically significant decrease in dose to the small and large bowel and kidneys, while maintaining excellent planning target volume coverage. Further studies should be done to correlate the clinical significance of these findings. © 2012 Elsevier Inc.

Keywords: Proton, IMRT, Pelvis, Gynecologic, Adjuvant, Dosimetry

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Conflict of interest: none.

Int J Radiation Oncol Biol Phys, Vol. 82, No. 3, pp. e477–e484, 2012
0360-3016/$ - see front matter
doi:10.1016/j.ijrobp.2011.07.012

by 11%, and in IMPT/IMRT by 32%. PSPT/IMRT and IMPT/IMRT showed statistically significant reductions in body $V_{5\text{-}20}$ and $V_{5\text{-}15}$, respectively. The dose received by half of both kidneys was reduced by PSPT/IMRT and IMPT/IMRT. Compared with IMRT alone, PSPT/IMRT and IMPT/IMRT had a statistically significant decrease in dose to the body, small and large bowel and kidneys, while maintaining excellent planning target volume coverage.

Introduction

Gynecologic malignancies represent a significant threat to women's health, with approximately 11,070 cases of cervical cancer and 40,100 cases of endometrial cancer annually (1). For patients with locally advanced cervical cancer, the standard therapy involves combination cisplatin chemotherapy and external-beam radiotherapy combined with intracavitary brachytherapy (2). The adjuvant treatment of high-risk endometrial cancer after hysterectomy often includes radiotherapy in addition to chemotherapy (3). In patients with pathologically positive or radiographically suspicious para-aortic lymph nodes, the external-beam radiation portal can be extended to cover the para-aortic nodal region.

External-beam radiotherapy for cervical and endometrial cancer has been classically delivered using either a two-field or four-field conventional approach. Intensity-modulated radiotherapy (IMRT) is now often used to improve normal tissue sparing after hysterectomy or for patients with intact uterus (4). Lian *et al.* (5) reported that IMRT resulted in excellent coverage of the tumor bed and improved sparing of organs at risk (OARs), including bowel, bladder, and rectum; however, this was at the expense of increased integral dose (ID) to surrounding normal tissue and the skeleton. Intensity-modulated radiotherapy has also been used to treat the pelvis and para-aortic region in women with gynecologic malignancies and has been found to be safe and tolerable, with improved sparing of normal tissues (4, 6, 7).

Proton therapy, with its characteristic Bragg peak, holds the promise of further reducing toxicity to surrounding OARs to facilitate dose escalation, particularly in patients receiving combined-modality therapy, for whom toxicity is enhanced. Several techniques exist for the administration of proton RT, including passive scatter proton therapy (PSPT) and intensity-modulated proton therapy (IMPT). Passive scatter proton therapy is effective in decreasing the dose distally. However, it is more difficult to conform to a complex target with PSPT. In contrast, IMPT uses scanning beam technology that simultaneously modulates intensities to take into account both normal tissue dose constraints and target coverage (8).

To evaluate the utility of adjuvant proton RT in the treatment of gynecologic malignancies, we performed a dosimetric comparison of treatment plans consisting of IMRT to the pelvic region, along with either PSPT or IMPT to the para-aortic lymph nodes. Our objective was to assess whether these combined techniques were able to provide adequate dose coverage to the targets while reducing the dose to OARs when compared with plans using IMRT only, and to determine which treatment planning approach was superior.

Methods and Materials

Study population

Approval for this retrospective dosimetric study was obtained from the institutional review board at the University of Pennsylvania. Ten consecutive patients treated with IMRT to the para-aortic and pelvic nodes at our institution from 2006 to 2008 were identified (9–11). Eight of the 10 patients had previously undergone a total abdominal hysterectomy and bilateral salpingo-oophorectomy, with pelvic and/or para-aortic lymph node dissection. Diagnoses included cervical carcinoma, uterine carcinosarcoma, papillary serous carcinoma of the peritoneum, and clear cell and endometrioid endometrial carcinoma.

Definition of target volume

The pelvic clinical target volume (CTV) was defined for cervical cancer as the primary tumor and for endometrial cancer as the vagina and paravaginal tissues as well as the regional lymph nodes (para-aortic, common iliac, external iliac, internal iliac, and obturator). The pelvic CTV also included the presacral nodes in patients with cervical cancer or endometrial cancer with cervical involvement. The para-aortic portion of the planning target volume (PTV) was contiguous with the pelvic portion and encompassed the aorta and inferior vena cava with an initial 7-mm margin to the CTV and a 1-cm margin to the PTV. For cervical and