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A novel dynamic field-matching technique for treatment of patients with para-aortic node-positive cervical cancer: Clinical experience

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ABSTRACT

Aim: To report outcomes for patients with para-aortic lymph node positive cervical cancer treated with a dynamic field-matching technique.

Background: PET staging of cervical cancer has increased identification of patients with para-aortic lymph node metastasis. IMRT enables dose escalation in this area, but matching IMRT fields with traditional whole pelvis fields presents a challenge.

Materials and methods: From 2003 to 2012, 20 patients with cervical cancer and para-aortic lymph node metastasis were treated utilizing the dynamic field-matching technique. As opposed to single-isocenter half-beam junction techniques, this technique employs wedge-shaped dose junctions for the abutment of fields. We reviewed the records of all patients who completed treatment with the technique and abstracted treatment, toxicity, and disease-related outcome data for analysis.

Results: Median prescribed dose to the whole pelvis field was 45 Gy and para-aortic IMRT field 50.4 Gy. All but 3 patients underwent HDR (13 pts) or LDR (4 pts) brachytherapy. All patients developed lower GI toxicity; 10 grade 1, 9 grade 2, and 1 grade 4 (enterovaginal fistula). Median DFS was 12.4 months with 1 and 2-year DFS 60.0% and 38.1%. One-year OS was 83.7% and 2-year OS, 64.4%. A total of 10 patients developed recurrence; none occurred at the matched junction.

Conclusions: The dynamic field-matching technique provides a means for joining conventional whole pelvis fields and para-aortic IMRT fields that substantially reduces dose deviations at the junction due to field mismatch. Treatment with the dynamic matching technique is simple, effective, and tolerated with no apparent increase in toxicity.

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1. Background

The development and increased utilization of FDG PET for cervical cancer staging has contributed to increased diagnosis of metastases to the para-aortic lymph nodes.[1–5] Intensity modulated radiation therapy (IMRT) enables definitive treatment of para-aortic target volumes with escalated doses of radiation while simultaneously sparing the adjacent organs at risk including the small bowel, spinal cord, and kidneys.[6–9] Though IMRT for postoperative pelvic radiation treatment for cervical cancer is well established, conventional 3-D conformal four-field pelvic RT remains a standard of care and is often preferred for intact cervical cancer.[10] Matching fields from both IMRT treatment for the para-aortic fields and conventional 4-field conformal treatment fields for the whole pelvis can prove challenging, often leading to significant dose inhomogeneities at the field junction.

2. Aim

Here we introduce a novel dynamic field matching technique to minimize inhomogeneities. We also report disease-related outcomes, toxicities, and patterns of failure from a series of 20 patients successfully treated with the technique.

3. Materials and methods

3.1. *Treatment planning for dynamic field matching*

Conventional field matching techniques, such as single isocenter half beams (SIHB), are prone to dose inhomogeneity due to imperfect mechanical accuracy of the linear accelerator. To minimize such inhomogeneities at the junction of para-aortic IMRT fields and static 3D conformal pelvic fields, we adopted the dynamic field matching technique that was initially developed for matching head-and-neck IMRT fields with the static supraclavicular field. The dynamic field match technique has been described in great detail in a previous publication, and we describe it only briefly here.[11]

Because dose inhomogeneity caused by the mismatch of abutting fields is proportional to the dose gradient at the field edges that constitute the match line, the dynamic field matching technique aims to reduce the dose gradient at these edges to minimize dose inhomogeneity. To achieve this, the superior borders of the pelvic fields are moved continuously (either open up or close down) over a 3 cm range (from 1.5 cm above to 1.5 cm below the conventional match line) during treatment, producing a 3 cm tapered dose junction. The para-aortic IMRT fields, which are purposely made to overlap with the pelvic fields by 3 cm, are optimized with consideration of the wedge-shaped dose contribution from the pelvic field to generate a complementary wedge at their inferior borders. The two sets of fields, which merge gradually, combine to deliver a homogeneous dose in the match zone. The two mutually complementing wedge shaped dose distributions at the field junctions effectively serve as a continuous match line feathering over a 3 cm range. Fig. 1 compares typical dose profiles of SIHB and dynamic field match techniques. The dose gradient for each component field is much less steep in the case of the dynamic field matching technique. These low gradient junctions help reduce dose heterogeneities resulting from patient setup error or imperfect mechanical calibration of the jaws. Fig. 2 demonstrates the dosimetric advantage of dynamic field match over the conventional SIHB method. For −3 mm to +3 mm overlap of the abutting fields, substantial dose heterogeneities are generated with the SIHB method (Fig. 2 left). These heterogeneities are greatly suppressed with the dynamic matching technique (Fig. 2 right).

To generate a plan with the dynamic matching technique a commercial treatment planning system (Eclipse; Varian Medical Systems, Palo Alto, CA) was used. A conventional static 4-field 3DCRT plan is first generated using the MLC to shape the field apertures. The MLC is oriented such that the leaves move in the superoinferior direction. To generate the 3 cm wedge junction, the static MLC leaf sequences are converted to dynamic ones using in-house software, such that the leaves shaping the superior field borders move continuously from 1.5 cm below to 1.5 cm above the conventional match line during treatment. The pelvic plan is then recalculated with the dynamic MLC using fixed monitor units that have been calculated previously. For the para-aortic IMRT fields, the PTV is extended 1.5 cm inferior to the conventional match line. The IMRT plan is optimized to cover the extended PTV by inclusion of the dose contribution from the pelvic fields, producing another wedge junction to complement that of the pelvic fields. To avoid field overlap beyond the 3 cm match zone, the inferior borders of the IMRT fields, which were adjusted automatically by the treatment planning system to fit the dynamic MLC fields, are then manually closed to 1.5 cm inferior to the match line using collimator jaws and the plan is recalculated.

3.2. *Clinical data collection and analysis*

We retrospectively reviewed the records of all cervical cancer patients who completed treatment with the dynamic matching technique at our institution between 2003 and 2012. Data abstracted from the chart included patient demographic information, disease stage and features, radiation technique and doses, details of concurrent chemotherapy. Acute and late gastrointestinal and genitourinary toxicities were recorded from the medical record and graded using RTOG acute and late radiation morbidity scoring criteria.[12,13] For patterns-of-failure and actuarial disease related outcome analyses, we recorded first site of failure, date of disease failure, date of death, and date of last follow-up and calculated time to event or censorship from the date of diagnosis. Failure was considered local if recurrence occurred at the site of original disease, regional if elsewhere within the pelvis or PA lymph node chain, and distant if at another site. Locoregional control (LRC), disease-free survival (DFS), and overall survival (OS) estimates were determined by the Kaplan–Meier method utilizing SPSS Statistics 22.0 for Windows (IBM SPSS, Chicago, IL).

4. Results

From 2003 to 2012, 20 patients completed curative-intent treatment utilizing the dynamic matching technique after staging