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Evaluation of pelvic lymph node coverage of conventional radiotherapy fields based on bony landmarks in high risk prostate cancer patients using virtual simulation

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Abstract

Virtual simulation refers to a method of delineating the tumour or treatment field. Field placement has resulted in more irregular shaped smaller fields as compared to conventional radiotherapy treatment fields for prostate cancer. The aim of this study was to evaluate pelvic lymph node coverage of conventional radiotherapy fields based on bony landmarks in high risk prostate cancer patients using virtual simulation based nodal mapping by using blood vessels as surrogate markers.

Materials and methods Forty patients with high risk stage T3N1 prostate cancer underwent virtual simulation using a computed tomography (CT) scanner. Gross tumor volume (GTV), clinical target volume (CTV) and planning target volume (PTV) were outlined on the unenhanced CT images. Unenhanced images were used as part of the institutional protocol.

All pelvic lymph nodes were contoured by using pelvic vessels as surrogate markers. The vessel contours were hidden by an option available in the planning software of the CT scanner. Thereafter conventional radiotherapy fields were drawn on digital reconstructed images (DRIs). The hidden vessel-contours were made visible again and distances were measured at different points of antero-posterior (AP) and lateral fields. Distances > 5 mm or more between the contoured nodes and the field borders were considered acceptable.

Results The antero-posterior (AP) fields showed inadequate coverage of the obturator lymph nodes at the level of the acetabulum (mean distance 2.0 mm p value 0.002). The lateral fields showed inadequate coverage of the sacral lymph nodes at the level of the second sacral vertebra (mean distance -0.47 mm p value 0.003) .

Conclusion The conventional pelvic fields for high risk prostate cancer do not give optimal nodal coverage. It is of utmost importance that the blocks to shield the rectum and femoral heads are fabricated with precision in order to achieve optimal nodal coverage.

Keywords
Shielding, nodal contouring

Introduction

External beam radiotherapy (EBRT) for high risk T2b or >, baseline prostate specific antigen (PSA) > 20 ng/ml or Gleason score > 8 prostate cancer has shown similar 5, 10 and 15 years recurrence and survival rates as radical prostatectomy [1,2]. The radiotherapy oncology group 94-13 (RTOG 94-13) trial has shown better progression free survival for high risk prostate cancer patients when treated with whole pelvis (WP) fields to cover pelvic lymph nodes followed by prostate boost compared to prostate only fields [3,4]. The lymphatics drain from the prostate gland to the internal iliac nodes, external iliac nodes, obturator nodes and pre-sacral nodes. Traditionally, in order to cover the prostate, seminal vesicles and lymph nodes, the whole pelvis is commonly used in which (AP/PA) field borders are kept superiorly at the junction of the fifth lumbar and first sacral (L5/S1) vertebrae; inferiorly at the ischial tuberosities; laterally a margin of two centimeters beyond lateral pelvic brim and in the lateral fields the posterior border is kept at the junction of second and third sacral vertebrae (S2/S3) and the anterior border is placed at the symphysis pubis.

With the advent of CT based simulation (virtual simulation), the tumor and critical structures are directly visualized through CT data and, pelvic lymph nodes which are rarely visible if uninvolved, are contoured by taking blood vessels as surrogate markers [5].

Our aim for this study was to observe the pelvic lymph node coverage using conventional radiotherapy fields in high risk prostate cancer using CT based lymph nodes contouring.

Materials and method

All patients signed a written consent for radical radiotherapy. Forty patients with high risk prostate cancer were selected. All patients were simulated using a CT scanner. The unenhanced CT images were contoured for gross tumor volume (GTV), clinical target volume (CTV) and planning target volume (PTV). All uninvolved pelvic lymph nodes were considered as clinical target volumes lymph nodes (CTV-N) and were contoured by using pelvic vessels as surrogate markers according to radiation therapy oncology group (RTOG) criteria (Figure 1). Then all vessel contours were hidden by an option available in the planning system software of the CT scanner. The field borders for the conventional box field technique were drawn on the digitally reconstructed radiographs (DRRs) as shown in Figure 1: namely (1) AP/PA fields: superior border, L5-S1 inter-space; inferior border, ischial tuberosities ; lateral border, be consistent 2 cm lateral to pelvic brim (standard protocol), (2) lateral fields (right & left): anterior border, at symphysis pubis; posterior border, S2-S3 inter-space.

Distances were measured at levels of (1) bifurcation of the common iliac vessels artery and superior border of AP field, (2) external iliac vessels and lateral border of the AP field, (3) external iliac vessels and anterior border of the lateral field and (4) posterior border of lateral field to sacral lymph nodes. Distances more than 5 mm between contoured vessels and field borders were considered acceptable. The data were analyzed on SPSS version 16.0 and the significant values were tested by Student's t test.

Results

On the AP fields the mean distance of contoured lymph nodes (CTV-N) to the level of

the bifurcation of the common iliac vessels from superior border was 0.91 mm (0.50-1.50) (SD 0.28) p value = 0.28. The mean distance of contoured lymph nodes (CTV-N) at the level of external iliac vessels from lateral border was 0.85 mm (0.50-1.30) (SD 0.32) p value = 0.3. Above the level of the acetabulum, the mean distance from lateral border was 0.2 mm (0.00-0.9) (SD 0.32) p value 0.002. There was considerable shielding of the obturator nodes.

On the lateral fields the mean distance of contoured lymph nodes from the posterior border at level of S2 was -0.47 mm (0.5-1.0) (SD 0.1) p value = 0.003 showed a significance shielding of a sacral nodes by rectal shielding. The mean distance of CTV-N from the anterior border was 0.30 mm (0.00-1.10) SD (0.36) p value = 0.4, was not significant, but borderline.

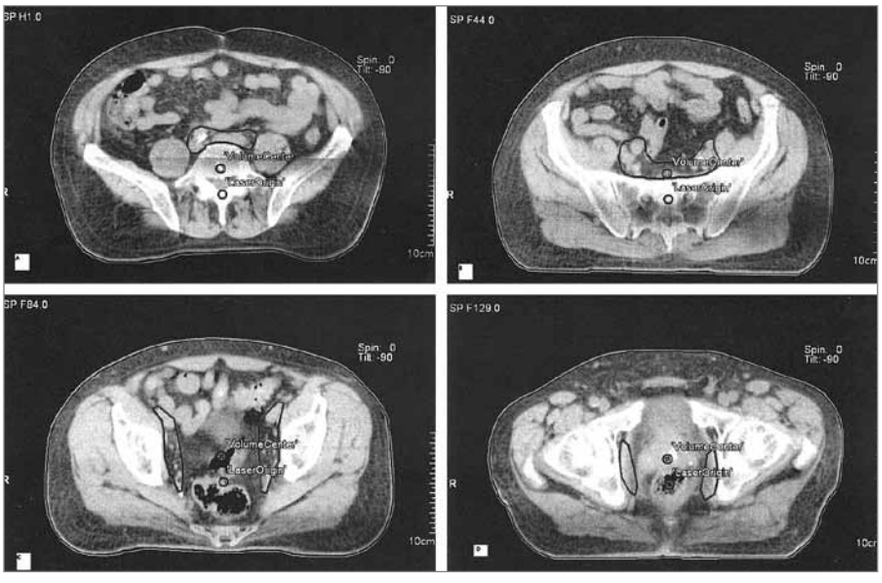

Figure 1: Contouring of pelvic lymph nodes according to RTOG criteria.

Discussion

Pelvic lymph node involvement has been considered the most important prognostic factor associated with disease recurrence in patients under going radical radiotherapy for localized prostate cancer. The chances of nodal metastases are dependent on the tumor size, Gleason score, and baseline PSA level. Patients with localized prostate cancer have been stratified into three risk groups. Among them, the high risk groups have a greater possibility of pelvic lymph node metastases [6]. To date the radiation therapy oncology group (RTOG) trial 94-13 has shown improved disease free survival for patients who received whole pelvis radiotherapy as compared to prostate only radiotherapy.

Traditionally, conventional four field radiotherapy fields are widely used to encompass the prostate, seminal vesicles and regional lymph nodes. With the advent of CT based simulation and treatment planning system radiation oncologists now can delineate the GTV, CTV, PTV, normal structures and the pelvic lymph nodes, instead of relying on the bony landmarks. Usually, uninvolved lymph nodes are not visible on CT images [7] thus blood vessels are contoured as surrogate markers for lymph nodes.

For this study, contouring was done on blood vessels as surrogate markers for lymph nodes because the pelvic lymph nodes are rarely visible. According to the RTOG guidelines [8], vessel contours are drawn from lower common iliac vessels up to their bifurcation at the lower sacro-iliac joints. The external iliac vessels are drawn to the acetabulum, the internal iliac vessels to the symphysis pubis and the sacral nodes to second sacral vertebra. All structures on the unenhanced

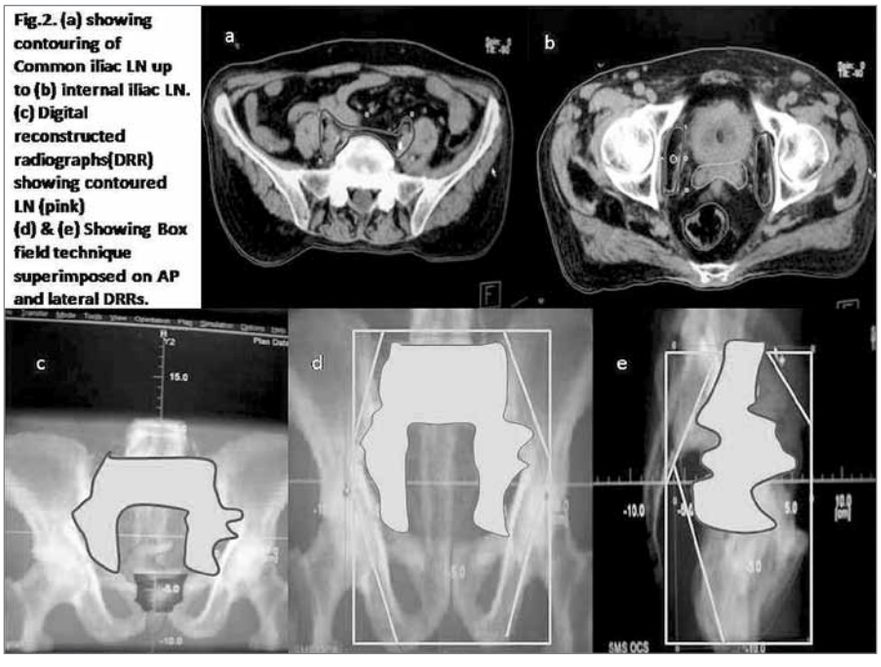

Figure 2: Methodology of the study. After contouring the lymph nodes based on vessels, all contoured vessels were hidden and conventional box field technique was drawn on AP and lateral on digitally reconstructed images (DRRs) box field drawn using bony landmarks. Contours were made visible again and distances were calculated between nodes and field borders.

images were contoured, however studies have shown that use of contrast media may provide better delineation of blood vessels [9]. In this study a 5 mm distance from contoured vessels was considered acceptable as we believed that such a distance could minimize the bowel volume within or around the nodes. One study by Finlay *et al.* [10] considered 15-20 mm distance as adequate. However researchers believe that margins of 15-20 mm would encompass more bowel which will enhance the radiation induced toxicity.

In this study the researchers calculated the distance between external iliac vessels and lateral border on the AP field at the level of three different points (lower sacro-iliac joint, lateral bony pelvis and at the acetabulum) and on the lateral field at the level of two points (mid and lower end of block for bowel). The distance between the sacral nodes and the border was calculated at the level of the second sacral vertebra.

In this study, the researchers found significant under-coverage of the obturator lymph nodes on AP fields in conventional fields especially if shaped field borders are drawn.

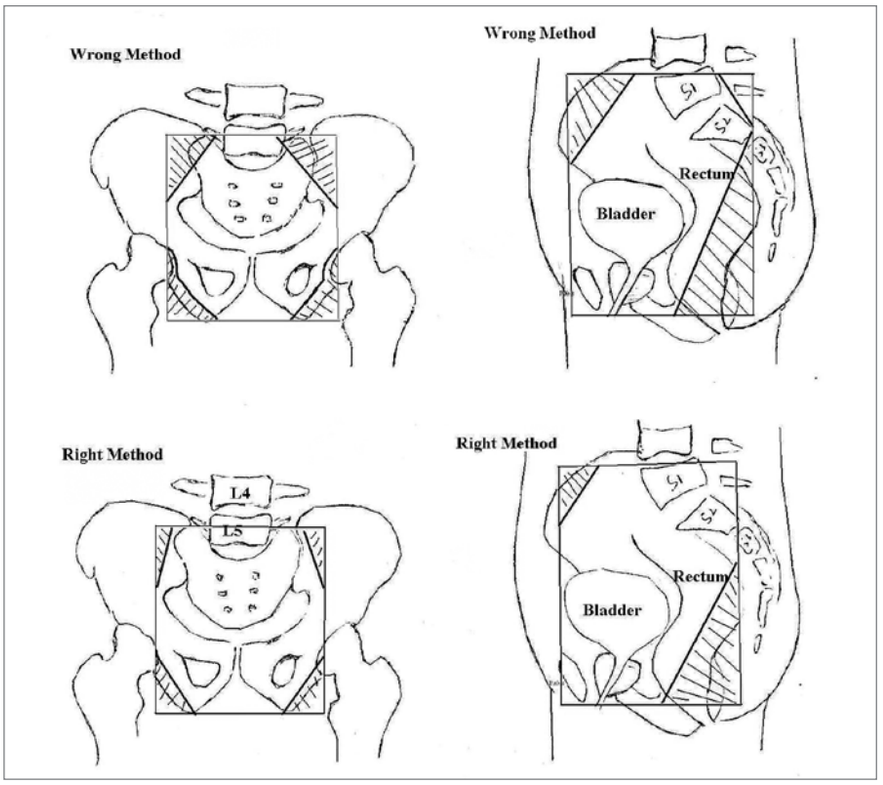

Figure 3: (A) Wrong methods for shielding of small bowel, femoral heads and rectum. (B) Correct and recommended methods for shielding of small bowel, femoral heads and rectum.

Such type of borders should not be used in centers that are using conventional radiotherapy fields because the literature suggests the obturator lymph node metastasizes around 30% in prostate confined cancer thus inadequate coverage can result in low tumor control probability [11].

Furthermore on the lateral fields the researchers noted significant shielding of sacral lymph nodes by shielding the rectal region. Although chances of sacral lymph node involvement are 10% [12] care should be taken while drawing the rectal shielding or blocks. We recommend that rectal blocks be drawn from the level of S3 vertebra rather than S2 vertebra if a conventional box field technique is used (Figure 3).

Conclusion

The conventional box field technique, based on bony landmarks, does not give optimal nodal coverage especially for obturator and sacral lymph nodes. CT based lymph node marking with vessel contouring gives more precise and adequate nodal coverage. Although unenhanced images are used to delineate the lymph nodes, contrast enhanced images may be more useful. For centers that are not using CT simulation and are using conventional methods we recommend the following as demonstrated in Figure 3:

1. On AP fields, the borders must be 1 to 2 cm away from the sacro-iliac joints.
2. On AP fields, shielding for femoral heads must not be shaped and to be drawn from level below the acetabulum.
3. On lateral fields, the rectal shielding to be drawn from S3 vertebra.
4. On lateral fields, the field borders to be drawn 1 cm away from the sacrum.

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